MANUAL

Nonresidential Manual for Compliance with the 1998 Energy Efficiency Standards for

• Nonresidential Buildings
• High-rise Residential Buildings
• Hotels [Motels]

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CALIFORNIA ENERGY COMMISSION

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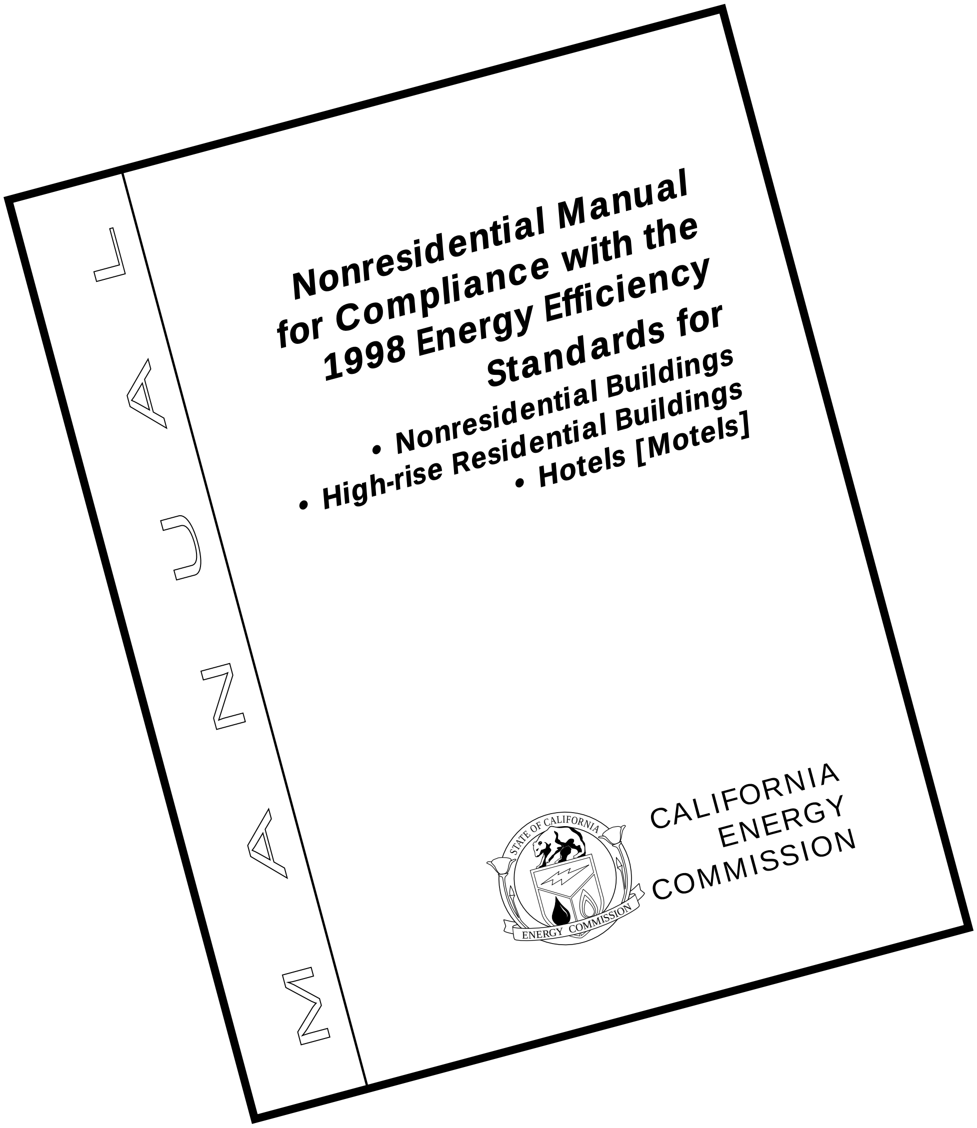

C A L I F O R N I A   E N E R G Y   C O M M I S S I O N

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Lastly, so many others contributed helpful suggestions, comments and criticism that are impossible to show a complete list. However, their assistance is acknowledge and greatly appreciated.

Spite of all our efforts, omissions and errors are certain to occur; these, of course, are attributed to the authors alone. If a Manual user discovers an error or has a suggestion, we ask that it be brought to our attention of the Energy Efficiency Hotline and they can be reached at 1-800-772-3300 (California Only) or 916-654-5106.

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Abstract

Section 25402.1 of the Public Resources Code requires that the California Energy Commission (Commission) make available compliance materials, including an energy conservation manual. The *Nonresidential Manual for Compliance with the 1998 Energy Efficiency Standards* (P400-98-005) (*Manual*) is provided to meet the requirement of this section. This *Manual* becomes effective July 1, 1999 and supersedes *the Nonresidential Manual for Compliance with the 1995 Energy Efficiency Standards* (P400-95-005), and all other previous manuals, notices, and interpretations explaining compliance with the *Energy Efficiency Standards* (*Standards*) for Nonresidential Buildings, High-Rise Residential Buildings and Hotels/Motels.

The Manual includes compliance method descriptions, calculation procedures, technical data, examples, and sample compliance forms for meeting the *Standards* for Nonresidential Buildings, High-Rise Residential Buildings, and Hotels/Motels. The chapters in this *Manual* refer to, paraphrase, or extract the *Standards* as promulgated by the Commission and as compiled in California's *Uniform Building Code*. This *Manual* is not a substitute for the Standards, and it should be used in conjunction with a current copy of the *Standards*, or a current copy of *California's Uniform Building Code*.

Table of Contents

ABSTRACT

TABLE OF CONTENTS i

LIST OF FIGURES ix

LIST OF EXAMPLES xi

LIST OF TABLES xiii

LIST OF EQUATIONS xv

Chapter 1: Introduction

1.0 CHAPTER OVERVIEW 1-1

1.1 THE ENERGY STANDARDS 1-1

1.1.1 Legal Requirements 1-2

1.1.2 Organization of Standards 1-2

1.1.3 California Climate Zones 1-2

1.2 BASIC APPROACHES TO COMPLIANCE 1-5

1.3 HISTORY OF THE STANDARDS 1-7

1.4 CHANGES IN THE 1995 STANDARDS 1-8

1.4.1 Structural 1-8

1.4.2 Technical 1-8

1.5 ORGANIZATION OF THIS MANUAL 1-10

Chapter 2: Scope and Application

2.0 CHAPTER OVERVIEW 2-1

2.1 INTRODUCTION 2-1

2.1.1 When Standards Apply 2-1

2.1.2 Basic Scope and Application Concepts 2-3

A: Conditioned Space Definitions 2-3

B: Occupancies 2-6

2.2 APPLICATION SCENARIOS 2-7
2.2.1 Unconditioned Space 2-7
2.2.2 Newly Conditioned Space 2-7
2.2.3 New Construction in Existing Buildings 2-9
2.2.4 Alterations to Occupied Spaces 2-9
2.2.5 Additions 2-11
2.2.6 New Buildings 2-12
A: Speculative, Known Occupancy 2-12
B: Speculative, Unknown Occupancy 2-13
C: Mixed Use 2-13
D: Semi-Conditioned 2-14
2.2.7 Change of Occupancy 2-14
2.2.8 Repair 2-14

Chapter 3: Building Envelope

3.0 CHAPTER OVERVIEW 3-1
3.1 INTRODUCTION 3-2
3.1.1 Envelope Compliance Approaches 3-2
A: Prescriptive Approach 3-2
B: Performance Approach 3-2
3.1.2 Basic Envelope Concepts 3-3
A: Definitions 3-3
B: Insulation R-value 3-7
C: Overall Assembly U-value 3-7
D: Wood Frame U-values 3-7
E: Metal Frame U-values 3-9
F: Masonry U-values 3-10
G: Heat Capacity 3-11
H: Fenestration U-values 3-12
I: Solar Heat Gain Coefficient 3-13
J: Relative Solar Heat Gain 3-13
3.2 ENVELOPE DESIGN PROCEDURES 3-15
3.2.1 Mandatory Measures 3-15
A: Doors, Windows and Skylights 3-15
B: Joints and Openings 3-16
C: Insulation Materials 3-16
D: Demising Walls 3-16

3.2.2 Prescriptive Component Approach 3-17
A: Exterior Roofs and Ceilings 3-17
B: Exterior Walls 3-18
C: Demising Walls 3-18
D: Exterior Floors and Soffits 3-19
E: Windows 3-19
F: Skylights 3-21
G: Exterior Doors 3-22
3.2.3 Prescriptive Overall Approach 3-22
A: Overall Heat Loss 3-24
B: Overall Heat Gain 3-26
3.2.4 Performance Approach 3-29
A: Modeling Envelope Components 3-29
3.2.5 Alterations 3-30
3.3 ENVELOPE PLAN CHECK DOCUMENTS 3-30
3.3.1 ENV-1: Certificate of Compliance 3-31
3.3.2 ENV-2: Envelope Component Method 3-39
3.3.3 ENV-2: Overall Envelope Method 3-43
3.3.4 ENV-3: Metal Framed Assembly 3-53
3.3.5 ENV-3: Masonry Wall Assembly 3-56
3.3.6 ENV-3: Wood Frame Assembly 3-59
3.4 ENVELOPE INSPECTION 3-62

Chapter 4: Mechanical Systems

4.0 CHAPTER OVERVIEW 4-1
4.1 INTRODUCTION 4-2
4.1.1. Mechanical Compliance Approaches 4-2
4.1.2. Basic Mechanical Concepts 4-3
A. Definitions of Efficiency 4-3
B. Definitions of Spaces and Systems 4-4
C. Types of Air 4-5
D. Air Deliver System 4-6
E. Attics and Return Plenums 4-6
F. Zone Reheat, Recool and Air Mixing 4-6
G. Economizers 4-7

H. Unusual Sources of Contaminants 4-8
I. Demand Control Ventilation 4-8
J. Intermittently Occupied Spaces 4-8

4.2 MECHANICAL DESIGN PROCEDURES 4-9
4.2.1 Mandatory Measures 4-9
A. Equipment Certification 4-9
B. Control Equipment Certification 4-10
C. Pilot Lights 4-10
D. Outdoor Ventilation 4-10
E. Natural Ventilation 4-11
F. Mechanical Ventilation 4-12
G. Ventilation System Operation and Controls 4-16
H. Required Controls for Space Conditioning Systems 4-21
I. Requirements for Pipe Insulation 4-26
J. Requirements for Ducts and Plenums 4-28
K. Service Water Systems 4-29
L. Pool/Spa Heating Systems 4-31

4.2.2 Prescriptive Approach 4-31
A. Sizing/Equipment Selection 4-31
B. Load Calculations 4-32
C. Fan Power Consumption 4-34
D. Space Conditioning Zone Controls 4-37
E. VAV Zone Controls 4-38
F. Economizers 4-38
G. Supply-Air Temperature Reset Control 4-40
H. Electric Resistance Heating 4-41
I. Service Water Heating 4-41

4.2.3 Performance Approach 4-41
A. Compliance with a Computer Method 4-42
B. Modeling Mechanical System Components 4-42

4.2.4 Alterations/Additions 4-42

4.2.5 Application to Major Systems Types 4-42

4.3 MECHANICAL PLAN CHECK DOCUMENTS 4-57
4.3.1 MECH-1: Certificate of Compliance 4-57

4.3.2 MECH-2: Mechanical Equipment Summary 4-69

4.3.3 MECH-3: Mechanical Ventilation 4-75

4.3.4 MECH-4: Mechanical Sizing and Fan Power 4-78

4.4 MECHANICAL INSPECTION 4-82

Chapter 5: Lighting Systems

5.0	CHAPTER OVERVIEW			5-1
5.1	INTRODUCTION			5-2
	5.1.1	Lighting Compliance Approaches		5-2
	5.1.2	Basic Lighting Concepts and Definitions		5-3
		A.	Lighting Trade-Offs	5-3
		B.	Definitions	5-4
		C.	Occupancy Type	5-7
		D.	Lighting Controls	5-9
5.2	LIGHTING DESIGN PROCEDURES			5-10
	5.2.1	Mandatory Measures		5-10
		A.	Area Controls	5-10
		B.	Bi-Level Switching	5-11
		C.	Daylit Areas	5-11
		D.	Shut-Off Controls	5-16
		E.	Display Lighting	5-18
		F.	Exterior Lights	5-18
		G.	Tandem Wiring	5-18
		H.	Certified Automatic Lighting Control Devices	5-18
		I.	Certified Ballasts and Luminaires	5-20
		J.	High Rise Residential Living Quarters & Hotel/Motel Guest Rooms	5-21
	5.2.2	Prescriptive Approach		5-24
		A.	Complete Building Method	5-24
		B.	Area Category Method	5-25
		C.	Tailored Method	5-28
		D.	Simplification for Tenant Spaces	5-36
		E.	Summary	5-36
	5.2.3	Performance Approach		5-40
	5.2.4	Actual Lighting Power		5-40
		A.	Exempt Lighting	5-40
		B.	Actual Lighting Power Calculations	5-41
		C.	Automatic Lighting Control Credits	5-43
	5.2.5	Alterations		5-43
5.3	LIGHTING PLAN CHECK DOCUMENTS			5-46
	5.3.1	LTG-1: Certificate of Compliance		5-46
		A.	LTG-1 Part 1 of 2	5-46
		B.	LTG-1 Part 2 of 2	5-51
		C.	Sample Form: LTG-1	5-52

5.3.2	LTG-2: Lighting Compliance Summary		5-54
	A.	Actual Lighting Power	5-54
	B.	Allowed Lighting Power	5-54
	C.	Sample Form: LTG-2	5-56
5.3.3	LTG-3: Lighting Controls Credit Worksheet		5-57
	A.	Sample Forms: LTG-3	5-58
5.3.4	LTG-4: Tailored LPD Summary and Worksheet		5-59
	A.	LTG-4: Part 1 of 3	5-59
	B.	LTG-4: Part 2 of 3	5-60
	C.	LTG-4: Part 3 of 3	5-61
	D.	Sample Form: LTG-4	5-64
5.3.5	LTG-5: Room Cavity Ratio Worksheet (≥ 3.5)		5-67
	A.	Rectangular Spaces	5-67
	B.	Nonrectangular Spaces	5-67
	C.	Sample Form: LTG-5	5-68
5.4	LIGHTING INSPECTION		5-69

Chapter 6: Special Topics

6.0	CHAPTER OVERVIEW		6.1
6.1	PERFORMANCE APPROACH		6-2
6.1.1	Summary		6-2
6.1.2	Performance Concepts		6-2
	A.	Approval of Computer programs	6-2
	B.	The Energy Budget	6-3
	C.	Compliance With a Computer Method	6-4
	D.	Compliance Procedure	6-5
	E.	Application Scenarios	6-5
	F.	Professional Judgment	6-8
6.1.3	Analysis Procedures		6-9
	A.	Energy Budget	6-9
	B.	Source Energy Use	6-10
6.1.4	Performance Plan Check Documents		6-11
	A.	PERF-1: Performance Certificate of Compliance	6-13
	B.	ENV-1: Envelope Compliance Summary	6-13
	C.	ENV-3: Construction Assemblies	6-14
	D.	EXISTING-ENV: Performance Method	6-14
	E.	MECH-1: Mechanical Compliance Summary	6-14
	F.	MECH-2: Mechanical Equipment Summary	6-14

G. MECH-3: Mechanical Compliance Summary/ Mechanical Ventilation 6-14
H. LTG-1: Lighting Compliance Summary 6-14

6.1.5 Performance Inspection 6-14

6.2 HOTELS AND MOTELS 6-15
6.2.1 Introduction 6-15

6.2.2 Hotel/Motel Compliance Approaches 6-15

6.2.3 Basic Hotel/Motel Concepts 6-15

6.2.4 Hotel/Motel Compliance 6-15
A. Mandatory Measures 6-15
B. Prescriptive Compliance 6-16
C. Performance Compliance 6-17

6.2.5 Hotel/Motel Plan Check Documents 6-17

6.2.6 Hotel/Motel Inspection 6-17

6.3 HIGH-RISE RESIDENTIAL 6-17
6.3.1 Introduction 6-17

6.3.2 High-rise Residential Compliance Approaches 6-17

6.3.3 Basic High-rise Residential Concepts 6-18

6.3.4 High-rise Res. Compliance 6-18
A. Mandatory Measures 6-18
B. Prescriptive Compliance 6-18
C. Performance. Compliance 6-19

6.3.5 High-rise Res. Plan Check Documents 6-19

6.3.6 High-rise Res. Inspection 6-19

6.4 SAMPLE FORMS 6-19

APPENDICES

Appendix A: Compliance Forms
Appendix B: Materials Reference
Appendix C: California Design Location Data
Appendix D: Indoor Air Quality
Appendix E: Certified Computer Programs
Appendix F: Publications Directory
Appendix G: Glossary
Appendix H: Residential Water Heating and Lighting
Appendix I: Plan Check Guides and Inspection Checklists

LIST OF FIGURES

Figure 1-1	Organization of the Nonresidential Standards	1-3
Figure 1-2	California Climate Zones	1-4
Figure 1-3	Nonresidential Standards Flowchart	1-5
Figure 1-4	Organization of Chapters 3, 4 and 5	1-10
Figure 2-1	Type of Conditioned Space and Scope of Compliance	2-8
Figure 3-1	Requirements for Floor/Soffit Surfaces	3-4
Figure 3-2	Requirements for Roof/Ceiling Surfaces	3-5
Figure 3-3	Surface Orientations	3-5
Figure 3-4	Skylight Area	3-6
Figure 3-5	Slope of a Wall or Window (Roof or Skylight slope is less than 60°)	3-6
Figure 3-6	Overhand Dimensions	3-13
Figure 3-7	Graph of Overhang Factors	3-14
Figure 3-8	Roof/Ceiling Flowchart	3-18
Figure 3-9	Wall Flowchart	3-18
Figure 3-10	Floor/Soffit Flowchart	3-20
Figure 3-11	Window Flowchart	3-21
Figure 3-12	Skylight Flowchart	3-22
Figure 4-1	Typical Building Energy Use (Energy Efficiency Report, October 1990, California Energy Commission Publication No. 400-90-003	4-2
Figure 4-2	Integrated Air Economizer	4-7
Figure 4-3	Nonintegrated Air Economizer	4-7
Figure 4-4	Water Economizer	4-8
Figure 4-5	Pre-Occupancy Purge Flowchart	4-18
Figure 4-6	Proportional Control Zone Thermostat	4-21
Figure 4-7	Shut-Off and Setback Controls Flowchart	4-24
Figure 4-8	Service Water Heating Flowchart	4-30
Figure 4-9	Fan Power Consumption Flowchart	4-34
Figure 4-10	VAV Fan Performance Curve	4-36
Figure 4-11	Economizer Flowchart	4-39
Figure 4-12	Supply Air Reset Controls Flowchart	4-40
Figure 5-1	Lighting Energy Use (Lighting accounts for 29% of all commercial building electricity use in California)	5-2
Figure 5-2	Lighting Compliance Flowchart	5-3
Figure 5-3	Bi-Level Switching	5-12

Figure 5-4	Combined Bi-Level and Daylit Area Switching	5-13
Figure 5-5	Window Daylit Area	5-14
Figure 5-6	Skylight Daylit Area	5-15
Figure 5-7	Well Index (Efficiency of Well) Graph	5-15
Figure 5-8	Timed Manual Override	5-17
Figure 5-9	Occupant-sensing Device Shut-off	5-17
Figure 5-10	Tandem Wiring	5-19
Figure 5-11	Residential and Hotel/Motel Guestroom Kitchen Lighting Examples	5-22
Figure 5-12	Residential and Hotel/Motel Guestroom Bathroom Lighting Examples	5-23
Figure 5-13	Complete Building Method Flowchart	5-25
Figure 5-14	Area Category Method Flowchart	5-26
Figure 5-15	Calculating Lighting Area	5-26
Figure 5-16	Chandelier Dimensions	5-28
Figure 5-17	Tailored Method Flowchart	5-29
Figure 5-18	Throw Distances and Mounting Heights	5-33
Figure 5-19	Calculating the Task Area	5-34
Figure 5-20	Gross Sales Wall Area	5-35
Figure 5-21	RCR for Stack Lighting (see Example 5-14)	5-36
Figure 5-22	Lighting Power Density Calculation Flowchart	5-37
Figure 6-1	Annual Sources Energy Use Summary	6-4

LIST OF EXAMPLES

Example 2-1	Research Greenhouse	2-2
Example 2-2	Direct Heating	2-4
Example 2-3	Direct Heating	2-4
Example 2-4	Direct Cooling	2-4
Example 2-6	High-Rise Residential	2-6
Example 2-7	New Window	2-10
Example 2-8	New Lighting Fixture	2-10
Example 2-9	New Interior Partitions	2-11
Example 2-10	Altered Duct Work	2-11
Example 2-11	Chiller Replacement	2-11
Example 2-12	Adding a Mezzanine	2-11
Example 2-13	Energy Inefficient Addition	2-12
Example 2-14	Minor Occupancy	2-13
Example 3-1	RSHG Calculation	3-15
Example 3-2	Area Calculation	3-24
Example 3-3	Glazing Area Adjustments	3-25
Example 3-4	RSHG Determination	3-27
Example 3-5	Determining Weighting Factors	3-28
Example 3-6	Sample Notes Block – Envelope Mandatory Measures	3-34
Example 4-1	Efficiency Compliance	4-10
Example 4-2	Efficiency Compliance	4-10
Example 4-3	Natural Ventilation	4-11
Example 4-4	Ventilation for a Two-room Building	4-15
Example 4-5	Minimum VAV CFM	4-17
Example 4-6	Purge Period	4-18
Example 4-7	Purge with Natural Ventilation	4-18
Example 4-8	Purge with Occupancy Timer	4-18
Example 4-9	Maintenance of Ventilation System	4-20
Example 4-10	Direct Digital Control of Space Temperature	4-21
Example 4-11	Perimeter Systems Thermostats	4-22
Example 4-12	Office Occupancy Sensor	4-23
Example 4-13	Automatic Time Switches with Multiple Systems	4-23
Example 4-14	Thermostat with Sensors	4-23
Example 4-15	Time Control for Fan Coils	4-24
Example 4-16	Isolation Zones	4-25
Example 4-17	Isolation Zone Purge	4-25
Example 4-18	Pipe Insulation Thickness	4-27
Example 4-19	Duct Sealing	4-29

Example 4-20	Equipment Sizing	4-32
Example 4-21	25 HP Limit	4-35
Example 4-22	Filtration	4-35
Example 4-23	VAV Bypass System	4-36
Example 4-24	Calculation of Fan Power	4-37
Example 4-25	Minimum VAV CFM	4-38
Example 4-26	Heat Pump Sizing	4-41
Example 4-27	Series Fan-Powered Box	4-45
Example 4-28	Parallel Fan-Powered Box	4-45
Example 4-29	Dual-Fan Dual-Duct Fan Power	4-51
Example 4-30	Sample Notes – Mechanical Mandatory Measures	4-61
Example 5-1	Lighting Trade-Offs: General Lighting	5-3
Example 5-2	Lighting Trade-Offs: Display Lighting (Parts 1 & 2)	5-4
Example 5-3	Shut-off Control Override	5-11
Example 5-4	Manual Switches and Automatic Controls	5-11
Example 5-5	Effective Aperture Matrix	5-14
Example 5-6	Skylight/Daylit Area	5-14
Example 5-7	Skylight Effective Aperture	5-15
Example 5-8	Complete Building Method	5-25
Example 5-9	Area Category Method	5-27
Example 5-10	Chandelier Wattage Allowance	5-28
Example 5-11	Office Task Duration	5-30
Example 5-12	RCR Calculation	5-31
Example 5-13	Private Office	5-33
Example 5-14	Stack Lighting RCR	5-35
Example 5-15	Simplified Lighting Flowchart, New Building	5-38
Example 5-16	Simplified Lighting Flowchart, Alteration	5-38
Example 5-17	Simplified Lighting Flowchart, Retail/Grocery Combination	5-39
Example 5-18	Track Lighting Power	5-42
Example 5-19	Medium Base Fixture Lighting Power	5-42
Example 5-20	Sample Notes: Lighting Mandatory Measures	5-49
Example 6-1	Performance Trade-offs	6-4

LIST OF TABLES

Table 1-1	History of Standards and Manuals	1-7
Table 3-1	Standard Air Film R-values	3-8
Table 3-2	Wood Framed Assembly U-values (excerpt from Table B-2, Appendix B)	3-8
Table 3-3	Wood Framing Percentage	3-9
Table 3-4	Metal Framed Assembly U-values (excerpt from Table B-2)	3-9
Table 3-5	Metal Framing Factors	3-10
Table 3-6	Properties of Hollow Unit Masonry Walls (excerpt from Table B-4)	3-10
Table 3-7	Properties of Solid Unit Masonry and Solid Concrete Walls (excerpt from Table B-5)	3-11
Table 3-8	Effective R-Values for Interior Insulation Layers on Structural Mass Walls (excerpt from Table B-6)	3-11
Table 3-9	Thermal Mass Properties	3-11
Table 3-10	Default Fenestration Product U-Values	3-12
Table 3-11	Default Solar Heat Gain Coefficient	3-13
Table 3-12	Overhang Factors	3-14
Table 3-13	Maximum Air Infiltration Rates	3-15
Table 3-14	Certified Insulating Materials	3-16
Table 3-15	Roof/Ceiling Requirements	3-18
Table 3-16	Wall Requirements	3-19
Table 3-17	Floor/Soffit Requirements	3-20
Table 3-18	Window Requirements	3-20
Table 3-19	Skylight Requirements	3-21
Table 3-20	Nonresidential Requirements	3-23
Table 3-21	High-Rise Residential and Hotel/Motel Guest Room Requirements	3-23
Table 3-22	Temperature and Solar Factors	3-27
Table 3-23	Glazing Orientation Weighting Factors	3-28
Table 4-1a	Minimum Ventilation Rates	4-12
Table 4-1b	UBC Occupant Densities (sf/person)	4-13
Table 4-2	Required Minimum Ventilation Rate Per Occupancy	4-14
Table 4-3	Pipe Insulation Thickness	4-27
Table 4-4	Duct Insulation Requirements	4-29

Table 5-1	Effective Aperture Matrix	5-13
Table 5-2	Typical Efficacy of Luminaires	5-21
Table 5-3	Complete Building Method Lighting Power Density Values	5-24
Table 5-4	Area Category Method LPD Values	5-26
Table 5-5	Illuminance Categories for Tasks	5-29
Table 5-6	Typical RCRs for Flush/Recessed Luminaires (Task height 2.5 ft above floor)	5-31
Table 5-7	Illuminance Categories A-E	5-32
Table 5-8	Illuminance Categories F-I	5-32
Table 5-9	Mounting Height Adustments	5-33
Table 5-10	Power Savings Adjustments for Lighting Controls	5-44

LIST OF EQUATIONS

Equation 3-1	Relative Solar Heat Gain	3-14
Equation 3-2	Standard Building Heat Loss	3-24
Equation 3-3	Proposed Building Heat Loss	3-26
Equation 3-4	Standard Building Heat Gain	3-26
Equation 3-5	Proposed Building Heat Gain	3-28
Equation 3-6	Energy Use Goal	3-30
Equation 4-1	Insulation Thickness	4-27

Chapter 1: Introduction

1.0 CHAPTER OVERVIEW

This chapter is an introduction to the *1998 Energy Efficiency Standards for Nonresidential Buildings, High-Rise Residential Buildings and Hotels/Motels*, as well as this *Nonresidential Manual.* The first section (1.1) summarizes the reasons for having energy standards. The second section (1.2) introduces the basic approaches to complying with the *Standards*, and briefly discusses some of the compliance options available. This is followed by two sections that outline the history of the *Standards* (1.3 and 1.4) since their inception in 1978, and the changes brought about by the 1998 *Standards*. The final section (1.5) explains the organization of this *Manual.*

Chapter Contents

1.1	**The Energy Standards**	**1-1**
	1.1.1 Legal Requirements	1-2
	1.1.2 Organization of Standards	1-2
	1.1.3 California Climate Zones	1-2
1.2	**Basic Approaches to Compliance**	**1-5**
1.3	**History of the Standards**	**1-7**
1.4	**Changes in the 1998 Standards**	**1-8**
	1.4.1 Structural	1-8
	1.4.2 Technical	1-8
1.5	**Organization of This Manual**	**1-10**

1.1 REASONS FOR ENERGY STANDARDS

There are numerous reasons to use energy more efficiently in buildings. One of the most obvious benefits is comfort. For example, on a hot summer day no reasonable amount of air conditioning will keep us cool sitting in a room surrounded by clear glass windows without any shading. The *Energy Efficiency Standards* (hereafter *Standards*) help ensure that new buildings maintain a high level of comfort.

A second reason for energy efficiency is economics. Investing in building energy conservation helps ensure that buildings are affordable to operate both now and into the future. Most efficiency measures in the *Standards* have a pay back period of less than five years and produce a positive cash flow. California's per capita energy consumption is declining slightly in part because of building and appliance efficiency standards. Cost-effective investment in energy efficiency also helps all citizens of California by keeping utility rates lower.

The *Standards* also produce environmental benefits. The need for more energy has led to oil spills, acid rain, smog and other forms of pollution. California is especially susceptible to these problems. In addition, the energy created by burning fossil fuels may lead to global climate change as a result of the "Greenhouse Effect." By the year 2009, existing building standards will save more energy than seven average power plants could produce.

The National Academy of Sciences recently urged the entire country to follow California's lead to "make conservation and efficiency the chief element in energy policy." The first efficiency recommendation was simple: "adopt nationwide energy efficient building codes."

1.1.1 Legal Requirements

All new buildings in California must meet the *Standards* and the administrative requirements of the *California Code of Regulations,* Title 24, Parts 1 and 6. Some requirements in the *Appliance Efficiency Regulations* of Title 20, Sections 1601 - 1608, also apply.

The statutory basis for the *Standards* is Section 25402 of the *Public Resources Code,* which states:

> *The California Energy Commission shall:" Prescribe, by regulation, ...building design and construction standards that increase the efficiency in the use of energy for new residential and new nonresidential buildings. The standards shall be cost effective, when taken in their entirety, and when amortized over the economic life of the structure when compared with historical practice. ...Six months after the commission certifies an energy conservation manual... no city, county, city and county, or state agency shall issue a permit for any building unless the building satisfies the standards prescribed by the commission ..."*

The purpose of this *Manual* is to explain clearly how to comply with and enforce the current *Standards* for nonresidential buildings. The *Manual* is written as both a reference source and an instructional guide, and can be used by architects, builders, building owners, designers, energy consultants, enforcement agency personnel, engineers, mechanical contractors and others directly or indirectly involved in the compliance process.

The *Manual* is divided into six chapters, each describing how the *Standards* apply to specific building components or situations.

1.1.2 Organization of the Standards

The 1998 Manual is organized to indicate how the *Standards* apply to the various building systems and situations. This organization is shown graphically in Figure 1-1.

1.1.3 California Climate Zones

Since energy use depends partly upon weather conditions, which differ throughout the state, the Energy Commission has established 16 climate zones representing distinct climates within California (see Figure 1-2). These 16 climate zones are used with both the Residential and the Nonresidential *Standards*.

Detailed climate zone boundary descriptions and lists of locations within each zone are available in the Energy Commission publication California Climate Zone Descriptions for New Buildings, July 1995, (P400-95-041).

NOTE: cities may occasionally straddle two climate zones. In these instances, the exact building location and correct climate zone should be verified before any calculations are performed.

If a single building is split by a climate zone boundary line, it must be designed to the requirements of the climate zone in which 50 percent or more of the building is contained.

Figure 1-1: Organization of the Nonresidential Standards

Title 24, Part 1, Article 1 - Administrative Requirements

Title 20, Sections 1601 et seq. - Appliance Efficiency Regulations

Title 24, Part 6, Chapter 1 - Energy Efficiency Standards

Subchapter 1 - General Provisions - All Occupancies

- 100 - Scope
- 101 - Definitions and Rules of Construction
- 102 - Calculation of Source Energy Consumption

Subchapter 2 - Mandatory - Equipment Manufacture & Installation of Systems and Equipment

- 110 - Systems and Equipment - General
- 111 & 112 - Appliances and Space Conditioning Equipment
- 113-115 - Water Heaters, Pools & Spas, Natural Gas, Pilot Lights
- 116-118 - Doors, Windows, Joints Insulation
- 119 - Lighting Control Devices

Subchapter 3 - Mandatory - Mechanical Systems and Equipment

- 120 - Space Conditioning and Water Heating Systems and Equipment - General
- 121 - Requirements for Ventilation
- 122 - Required Controls for Space Conditioning Systems
- 123-124 - Requirements for Pipe and Duct Insulation

Subchapter 4 - Mandatory - Lighting Systems and Equipment

- 130 - Lighting General
- 131 - Required Lighting Controls
- 132 - Lighting Circuiting

Subchapter 5 - Performance and Prescriptive Approaches

- 140 - Choice of Performance/ Prescriptive
- 141 - Performance Budgets
- 142 - Prescriptive Approach
- 143 - Prescriptive Envelope
- 144-145 - Prescriptive Mechanical
- 146 - Prescriptive Lighitng

Subchapter 6 - Special Topics and Repairs

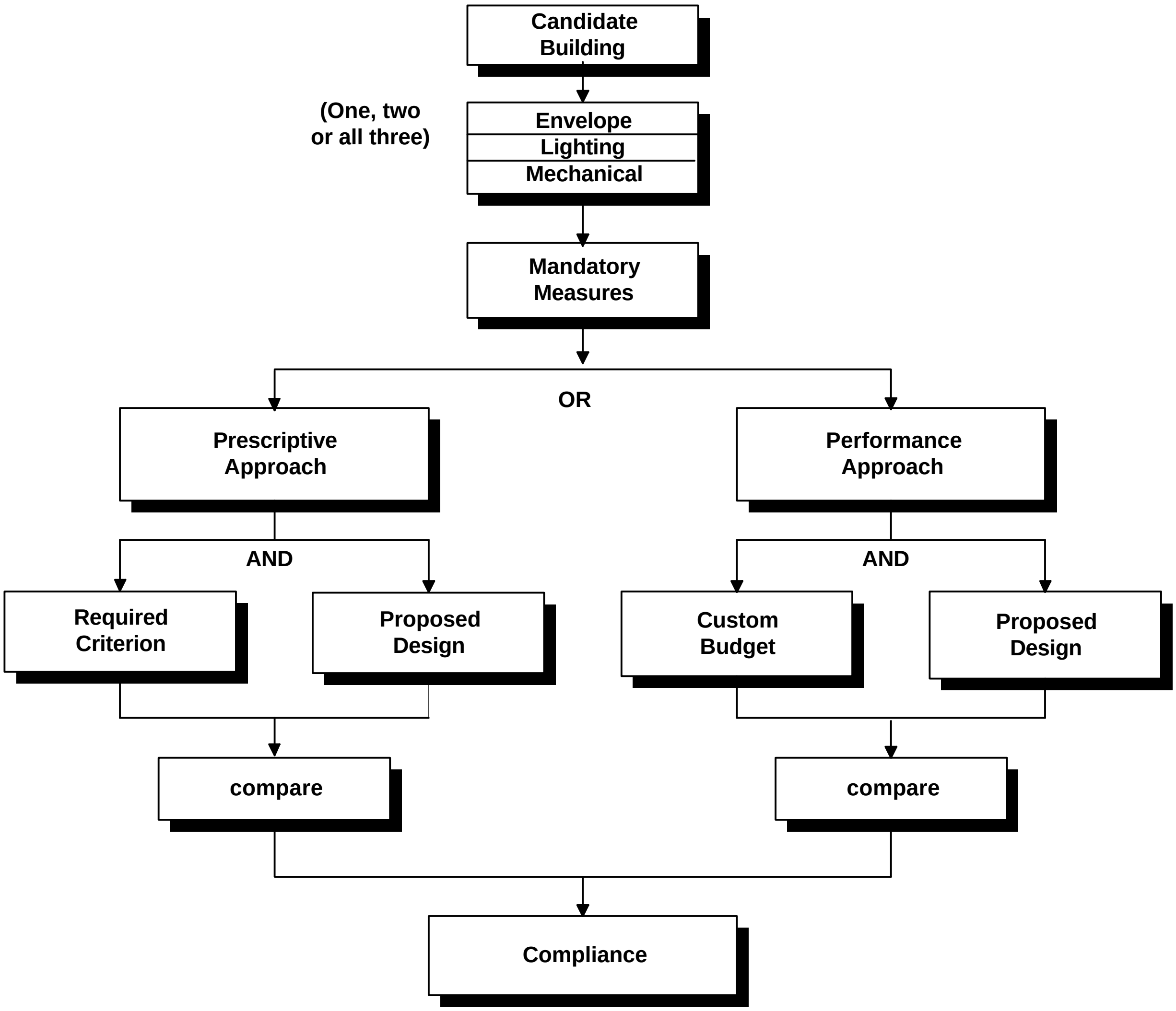
- 149 - Additions, Alterations and Repairs

Subchapters 7 & 8 - Low Rise Residential Building

- 150-152 - Mandatory, Performance & Prescriptive, Additions and Alterations

Figure 1-2: California Climate Zones

Figure 1-3: Nonresidential Standards Flowchart



1.2 BASIC APPROACHES TO COMPLIANCE

The *Standards* provide flexibility to the designer in choosing an approach to comply with the requirements. This section gives an introduction to the basic choices, or approaches, that are available. The details of how the different approaches apply to the building and its systems are covered in the following chapters.

There are two basic options for demonstrating that a building meets the requirements of the *Standards:* the prescriptive approach and the performance approach.

With either approach, certain mandatory measures always apply.

The *Standards* cover the three major components of a nonresidential building: the building envelope, the mechanical systems, and the lighting systems. A minor energy user, water heating, is also covered. Each component is typically the responsibility of a different design professional. The envelope is designed by an architect, the mechanical systems by a mechanical engineer, and the lighting systems by an electrical engineer. Each of the three components may be shown to comply independently under the prescriptive approach. Under the performance approach, *Standards* compliance may be shown for the envelope only, the envelope and mechanical systems, or for all three components.

Alternatively, the building (all three components) may be shown to comply as a whole under the performance approach when the permit application includes all three components.

Figure 1-3 graphically illustrates how the three nonresidential building components must each comply with their mandatory measures, and then either the prescriptive or performance approaches.

The mandatory measures for each of the three components are described in Chapters 3, 4, and 5.

The prescriptive approach is the simpler way to comply with the *Standards*. Each of the three building components complies separately from the others. The compliance procedures and documentation are also separate for the three.

The prescriptive approach for each component requires that the proposed system design be shown to meet specific energy efficiency criteria specified by the *Standards*. If the design fails to meet even one of the requirements, then the component does not comply with the *Standards*.

Prescriptive Envelope: The prescriptive envlope requirements are determined either by the Envelope Component Approach or the Overall Envelope Approach. These two approaches are described in detail in Chapter 3, beginning with an introduction in Section 3.2. The stringency of the envelope requirements varies according to climate zone and occupancy type.

Prescriptive Mechanical: The prescriptive mechanical requirements are described in detail in Chapter 4. The prescriptive *Standards* do not offer any alternative approaches, but specify hardware features and design procedures that must be followed.

Prescriptive Lighting: The prescriptive lighting requirements are determined by one of three methods: the Complete Building Method, the Area Category Method, or the Tailored Method. These three approaches are described in detail in Chapter 5, beginning with an introduction in Section 5.2.1. The allowed lighting under the *Standards* varies according to the requirements of the particular building occupancy or task requirements.

Performance Approach: The performance approach allows a wider variety of design strategies and provides greater flexibility than the prescriptive approach. It is based on an energy simulation model of the building. The *Standards* specify the method for determining an energy budget for the building. This is known as the *custom energy budget,* because it is generated on a case-by-case basis. This energy budget is the goal for energy efficiency that the building must meet.

Four basic steps are involved:

- Design the building with energy efficiency measures sufficient to meet the energy budget. (The prescriptive approach requirements provide a good starting point for the development of the design.)
- Demonstrate that the building complies with the mandatory measures (see Chapters 3, 4 and 5).
- Model the energy consumption of the building using an approved calculation method. This results in the energy budget.
- Model the energy consumption of the building using the proposed features. If the consumption is no greater than the energy budget, the building complies.

The designer is permitted to trade off different aspects of the building design, one against the other, when applications for more than one components permit are requested at the same time. If the final design does not exceed the energy budget, the design element is included in the building permit application.

1.3 HISTORY OF THE STANDARDS

The Organization of Petroleum Exporting Countries (OPEC) oil embargo of 1973 brought about an acute awareness of the need for an effective state energy policy. The Legislature created the State Energy Resources Conservation and Development Commission (Energy Commission) in 1974 to deal with energy-related issues, and mandated that the Energy Commission adopt conservation standards for new buildings. The Energy Commission first adopted such standards in 1977.

So-called "First Generation" standards for nonresidential buildings took effect in 1978. Those nonresidential standards remained in effect for all nonresidential occupancies until January 1987, when "Second Generation" standards took effect for office occupancies. Second Generation standards for retail and wholesale occupancies took effect in July 1988. Also in July 1988, all nonresidential lighting compliance was under the Second Generation standards, while envelope and space conditioning compliance requirements for nonresidential occupancies (except office and retail/wholesale buildings) remained the same ("First Generation") from 1978 until the *1992 Nonresidential Standards* took effect. Optionally, from July 1988 until July 1992, permit applicants could show compliance for First Generation occupancies using a Second Generation compliance method.

High-rise residential and hotel/motel occupancies were covered under the *1978 Residential Standards* until July 1992, when they were placed within the structure of *1992 Nonresidential Standards*. The first generation standards applied only to the building envelope. Lighting and mechanical systems (except electric resistance heating) in both high-rise resdential and hotel/motel buildings were not regulated until July 1, 1992.

The *1992 Nonresidential Standards* consisted of a major restructuring of the format of the *Standards.* The 1995 and 1998 *Energy Efficiency Standards* focus on compliance and implementation issues rather than developing new standards. Lighting allowances were updated for the first time in 10 years.

This section highlights the major changes included in the *1995 and 1998 Standards* for nonresidential buildings.

Table 1-1 summarizes the *History of the Standards and Manuals* in effect since 1978 and lists the name of the compliance manual that was used in conjunction with that set of *Standards*.

Table 1-1: History of Standards and Manuals

Date	Set of Standards	Compliance Manual
1978	First Generation Residential (including Hotels and High-rise)	Energy Conservation Design Manual for New Residential Buildings (2/78)
1978	First Generation Nonresidential	Energy Conservation Manual for New Nonresidential Buildings (10/77)
1983 to 1984	Second Generation Residential (excluding Hotels and High-rise)	Energy Conservation Manual for New Residential Buildings (Fall, 1984)
1987	Second Generation Nonresidential (only Office)	Energy Efficiency Manual, Designing for Compliance (12/86)
1988	Second Generation Nonresidential (Office and Retail/Wholesale)	Energy Efficiency Manual, Designing for Compliance (12/86)
1988	Second Generation Residential (excluding Hotels and High-rise)	Energy Conservation Manual for New Residential Buildings (7/88)
1992	Nonresidential Standards (includes Hotels and High-rise Residential)	Nonresidential Manual for Compliance with Energy Efficiency Standards (7/92)
1992	Residential Standards (excludes Hotels and High-rise)	Residential Manual for Compliance with Energy Efficiency Standards (7/92)
1995	Nonresidential Standards (includes Hotels and High-rise Residential)	Nonresidential Manual for Compliance with Energy Efficiency Standards (7/95)
1995	Residential Standards (excludes Hotels and High-rise)	Residential Manual for Compliance with Energy Efficiency Standards (7/95)
1998	Nonresidential Standards (includes Hotels and High-rise Residential)	Nonresidential Manual for Compliance with Energy Efficiency Standards (7/98)
1998	Residential Standards (excludes Hotels and High-rise)	Residential Manual for Compliance with Energy Efficiency Standards (7/98)

special documentation to substantiate *as built* conditions.

1.4 CHANGES IN THE STANDARDS

1.4.1 Structural

Beginning with the 1992 *Standards, there is* no longer a grandfather clause that allowed compliance for a building that began with a certain standard, to continue under that standard until the building was completely constructed. Also there was no reference to past standards on a permit application. These *Standards* apply to all nonresidential as well as to all high-rise residential, hotels, and motels since these occupancies more closely resemble nonresidential than residential in terms of their mechanical systems and energy use patterns.

The *Standards* apply only to the systems and portion of the building for which a building permit is sought. This simplifies both compliance and enforcement, virtually eliminating the need to consider other systems or parts of the building in the compliance process.

The prescriptive *Standards* do not permit energy efficiency trade-offs between systems. Each of the three sections, envelope, mechanical and lighting, stand alone.

The performance approach establishes the energy budget on a custom basis for each building. The custom budget is automatically generated by an approved computer program that is used to estimate the building's annual energy use.

The performance approach limits the range of options available for trade-off (items that can change between standard and proposed cases). Trade-offs are only allowed for those features specifically included in the building permit application, as well as for all existing conditions and systems that are to remain and are subject to the current *Standards* (see Section 6.1). Systems that will be installed under a future permit application are not available for trade-off. NOTE: the building department may require special documentation to substantiate *as built* conditions.

1.4.2 Technical

The *1998 Energy Efficiency Standards* become effective July 1, 1999.

A. SCOPE and APPLICATION:

- A new category of "semi-conditioned" building will comply with lighting requirements. A semi-conditioned building is a nonresidential building with conditioning that currently does not meet the definition of a directly conditioned—less than 5 Btu/hr/ft² of cooling, less than 10 Btu/hr/ft² of heating, evaporative cooling, wood heat, conditioned for a process environment below 55 or above 90° F.
- The definition of directly conditioned is changed to exclude from compliance spaces that are not *maintained* outside the comfort range (55 - 90°F), that is the temperature floats in and out of the comfort range, but are incapable of *operating and maintaining* the space within the comfort range.
- Definitions of mechanical cooling and mechanical heating remove the phrase "for the purpose of maintaining human comfort."

B. ENVELOPE:

- The heat gain and heat loss equations were updated for accuracy and the heat gain equation now considers the effects of opaque surfaces where it formerly considered only fenestration.
- Prescriptive high-rise residential requirements now include insulation for concrete raised floors (e.g., apartments with underground parking) to match low-rise requirements. R-4 is required in climate zones 12 and 15, and R-8 in climate zones 1, 2, 11, 13, 14 and 16.

- When a portion of an entire building's fenestration is repaired or replaced, or 50 square feet or less of glass is added, compliance with the solar heat gain coefficient requirements of Section 143 is not required.

- All manufactured fenestration products must have a label with the U-value and Solar Heat Gain Coefficient (SHGC). These values can be NFRC or default values. The default values are found in the *Standards*, Section 116.

- Glazed wall systems and overhead glazing do not need to be labeled. These products must still determine a U-value and SHGC using NFRC or default values.

- Field-fabricated fenestration does not need to be labeled. These products will use the default values. This term replaces site-built, and applies to products whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits and curtainwalls).

C. MECHANICAL:

- All pressure-sensitive tapes, mastics, aerosol sealants or other duct closure systems must meet applicable UL 181 requirements

- Drawbands Used with Flexible Duct shall:

  (a) be either stainless-steel worm-drive hose clamps or uv-resistant nylon duct ties.
  (b) have a minimum tensile strength rating of 150 pounds.
  (c) be tightened as recommended by the manufacturer with an adjustable tensioning tool.

- Prescriptive fan power limitations for variable air volume systems are changed to reflect improvements in technology and system efficiency. Individual VAV fans with motors over 25 HP (adjusted for air filtering systems) must meet one of the following:

  (a) The fan motor shall be driven by a mechanical or electrical variable speed drive.
  (b) The fan shall be a vane-axial fan with variable pitch blades.
  (c) The fan motor shall include controls that limit the fan motor demand to no more than 30% of the total design wattage at 50% of design air volume when static pressure set point equals 1/3 of the total design static pressure, based on certified manufacturer's test data.

- A new exception to prescriptive economizer requirements is provided for spaces or rooms with a dedicated space conditioning system where the use of outdoor air is detrimental to equipment or materials. Possible examples include computer room, telecommunications, and other equipment rooms.

D. LIGHTING:

- Reduced control credits for lumen maintenance (from 10 to 5%) and for combined occupancy sensor and lumen maintenance (from 37 to 25%).

- 22 new categories of building uses are added to the Area Category Method.

- Lighting levels in all compliance approaches are reduced to account for substituting T-8 lamps with electronic ballasts for T-12 lamps with magnetic ballasts. Reductions are based on the prevalence of fluorescent lighting in the building model.

1.5 ORGANIZATION OF THIS MANUAL

This *Nonresidential Manual* is organized into six chapters plus several appendices. Each chapter of the *Manual* covers a major set of related topics regarding compliance with the requirements of the *Standards*.

Chapter 1, this *Introduction,* serves as a brief overview of the *Standards* and this *Manual.*

Chapter 2 discusses the *Scope and Application* of the *Standards*, explaining when they apply to a particular building and discussing some application problems that may arise. Chapter 2 will help in deciding if the *Standards* apply to the project.

Chapters 3, 4 and 5 discuss the *Standards* in terms of the three major components: envelope, mechanical and lighting. These chapters are written to be largely stand-alone for the discipline to which it applies. For example, the HVAC system designer will find all the mechanical system requirements fully discussed in Chapter 4. Likewise, the building department's mechanical plan checker and inspector can concentrate on Chapter 4.

These three chapters are organized into subsections that address the major phases of a building project:

- The *Design* section discusses the requirements as they affect the design process; the principles of each requirement are explained and illustrated.

- The *Plan Check Documents* section is addressed to those who prepare the construction documents and compliance calculations for review by the building department's plan checker. It is also addressed to the plan checker. This section focuses on the specific information that must be included in the plans and on the compliance forms to adequately demonstrate compliance.

Each of the sections addresses the Mandatory Measures, the Prescriptive Approach and the Performance Approach.

The organization of these three chapters is illustrated in Figure 1-4.

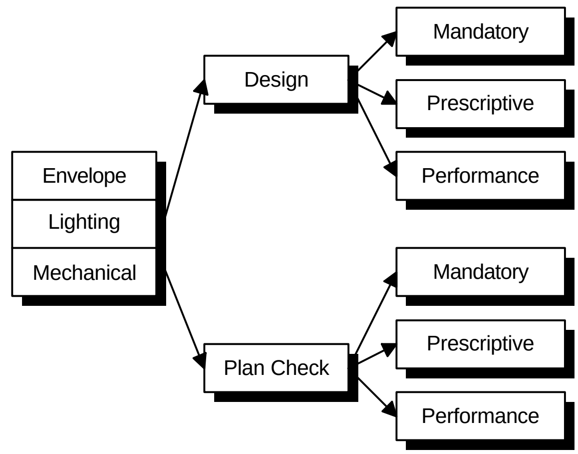


Figure 1-4: Organization of Chapters 3, 4 and 5

In addition to the major parts of these three chapters, there are two sections at the beginning of each chapter.

Chapter Overview - provides a brief overview of the chapter contents.

Introduction - provides basic information about the component and its compliance requirements:

> *Compliance Approaches* - explains the options available for compliance for the given building component.
>
> *Basic Concepts* - explains the definitions and technical concepts necessary to an understanding of the *Standards* requirements applicable to the component.

Chapter 6 - discusses several *Special Topics* that can apply to any of the components. This includes a discussion of the Performance Approach, High-rise Residential Buildings, and Hotels and Motels.

Appendices - contain reference tables, charts and definitions that support the implementation of the *Standards,* including data on construction assemblies, and Climate Zone Descriptions.

Tables of Contents and Index - at the front and back of the Manual - provide two types of cross-references to the material in the document.

Note: Two notation conventions are used throughout this *Manual* in making cross-references:

1. References to other locations within this *Manual* are called out by Section number:

   "see Section 3.2.2D"

2. Some references to the *1998 Energy Efficiency Standards* are called out by section "§" number: "§143(b)"

Chapter 1 Index

A

Aaddition · 1, 10
Administrative requirements · 2
Allowed lighting · 6
Alternative approaches · 6
Apartments · 8
Appliance Efficiency Regulations · 2
Application · 6, 8, 10
Application · 10
APPLICATION · 8
Approved computer program · 8
Architects · 2
Area · 6, 9
Area Category Method · 6, 9

B

Ballasts · 9
Basic approaches to compliance · 5
Building · 1, 2, 5, 6, 7, 8, 9, 10
Building codes · 2
Building component · 2, 6, 8, 10
Building envelope · 5, 7
Building permit · 6, 8

C

California Code of Regulations · 2
California Code of Regulations, · 2
Climate Zone · 1, 2, 4, 6, 8, 10
Comfort · 1, 8
Compliance · 1, 2, 5, 6, 7, 8, 9, 10
Compliance Manual · 7
Compliance Procedure · 6
Components · 2, 5, 6, 9, 10
Computer · 8, 9
Concepts · 10
Concrete · 8
Construction Documents · 10
Contractors · 2
Control Credits · 9
Controls · 9
Cooling · 8
Custom Budget · 8

D

Designer · 5, 6, 10
Directly Conditioned · 8
Documentation · 6, 8

E

Economizer · 9
Electric Resistance · 7
Electrical Engineer · 5
Energy Budget · 6, 8
Energy Conservation Manual · 2, 7
Energy Simulation Model · 6
Enforcement · 2, 8
Engineers · 2
Entire Building · 8
Envelope Component Approach · 6
Evaporative Cooling · 8
Exterior Door · 9

F

Fan Power · 9
Fenestration Products · 9
Field-Fabricated · 9
Floors · 8

G

Glazing · 9

H

Heat Gain · 8, 9
Heat Loss · 8
Heating · 5, 7, 8
High-Rise Residential · 7, 8
History Of Standards And Manuals · 7
Hotel/Motel · 7
Human Comfort · 8

I

Insulation · 8

L

Lamps · 9
Legal Requirements · 1, 2
Legislature · 6
Lighting · 5, 6, 7, 8, 9, 10
Lighting Systems · 5

M

Mandatory Measures · 5, 6, 10
Manufactured Fenestration Product · 9
Mechanical Cooling · 8
Mechanical Engineer · 5
Mechanical Heating · 8
Mechanical Systems · 5, 7, 8

N

New Buildings · 1, 2, 7
Notation Conventions · 11

O

Occupancy · 6, 9
Opaque · 8
Opaque Surface · 8
ORGANIZATION OF THIS MANUAL · 1, 10
Outdoor Air · 9

P

Performance Approach · 5, 6, 8, 10
Permit · 2, 6, 7, 8
Plan Check Documents · 10
Plan Checker · 10
Plans · 10
Prescriptive Approach · 5, 6, 10
Prescriptive Envelope · 6
Prescriptive Lighting · 6
Prescriptive Mechanical · 6
Process · 2, 8, 10

R

Raised Floors · 8
Residential Manual · 7
Residential Standards · 7
Retail · 7

S

Scope And Application · 10
SHGC · 9
Solar Heat Gain · 9
Solar Heat Gain Coefficient · 9
Space Conditioning · 7, 9
Space Conditioning System · 9
State Energy Policy · 6
Static Pressure · 9

T

Tailored Method · 6
Trade-offs · 8

U

U-value · 9

V

Variable Air Volume · 9

W

Wall · 9
Water Heating · 5
Wholesale · 7
Windows · 1

Z

Zones · 1, 2, 4, 8

Chapter 2: Scope and Application

S&A

2.0 CHAPTER OVERVIEW

This chapter discusses when and how the *Standards* apply to a building. The Introduction section (2.1) presents the basic scope of the *Standards.* It explains the definitions that must be understood to have a precise understanding of the scope and application.

The third section (2.2) explains the application of the *Standards* to a variety of typical nonresidential building and permitting situations. This chapter does not discuss the specific requirements of the *Standards*; these are discussed in Chapters 3, 4 and 5.

Chapter Contents

2.1	**Introduction**		**2-1**
	2.1.1	When Standards Apply	2-1
	2.1.2	Basic Scope and Application Concepts	2-3
		A: Conditioned Space Definitions	2-3
		B: Occupancies	2-6
2.2	**Application Scenarios**		**2-7**
	2.2.1	Unconditioned Space	2-7
	2.2.2	Newly Conditioned Space	2-7
	2.2.3	New Construction in Existing Buildings	2-9
	2.2.4	Alterations to Occupied Spaces	2-9
	2.2.5	Additions	2-11
	2.2.6	New Buildings	2-12
		A: Speculative, Known Occupancy	2-12
		B: Speculative, Unknown Occupancy	2-13
		C: Mixed Use	2-13
		D: Semi-Conditioned	2-14
	2.2.7	Change of Occupancy	2-14
	2.2.8	Repair	2-14

2.1 INTRODUCTION

2.1.1 When Standards Apply (§100(a)1, 2, 3)

The *Standards* apply to any new construction that requires a building permit, whether for an entire building or for adding a few lighting fixtures (Section 100). The primary enforcement mechanism of the *Standards* is through the building permitting process. Until the building department is satisfied that the building complies with all applicable code requirements, including the energy *Standards,* it may withhold the building permit (or, after construction, the occupancy permit).

The *Standards* apply only to the construction that is the subject of the building permit application (with the exception of existing spaces that are "conditioned" for the first time, in which case existing envelope and lighting systems also must show compliance with the *Standards*).

The *Standards* apply only to buildings that are *directly, indirectly or semi-conditioned* by *mechanical heating* or *mechanical cooling (*Section 100(a)). Subsection 2.1.2 provides detailed definitions of these terms.

A. Nonresidential Standards

The *1998 Energy Efficiency Standards for Nonresidential Buildings, High-Rise Residential Buildings, and Hotels/Motels* are effective after July 1, 1999. They apply to nearly all buildings not covered by the residential *Standards*. These include the following Uniform Building Code Occupancy Groups:

UBC Groups A, B, E, F, H, M, R (limited) and S

These buildings include (but are not limited to):

- Offices
- Retail and wholesale stores
- Grocery stores
- Restaurants
- Assembly and conference areas
- Industrial work buildings
- Commercial or industrial warehouses
- Schools
- Churches
- Theaters
- Apartment buildings with four or more habitable stories
- Hotels and Motels

The *Standards* do not apply to UBC Groups I and U. These groups include such buildings as hospitals, daycare, nursing homes, prisons, private garages and agricultural buildings.

The *Standards* also do not apply to buildings that fall outside the jurisdiction of California building codes, such as mobile structures.

The final exception to the *Standards* is qualified historic buildings, as defined in the State Historic Building Code (Title 24, Part 8) (exception to Section 100(a)).

Example 2-1: Research Greenhouse

Question

A company engaged in agricultural research has a greenhouse appended to its office building. It is devoted exclusively to cultivating exotic plants and is conditioned to maintain a set temperature of 80°F. Is it subject to glazing restrictions and envelope heat gain limits?

Answer

It depends upon the UBC Group designation of the greenhouse. If it is designated an agricultural building (Group U), then it is exempt from the Standards. If it is designated part of the B office occupancy, then it would be subject to the applicable glazing, lighting and other standards.

B. Residential Standards

The *1998 Energy Efficiency Standards for Low-Rise Residential Buildings* are also effective after July 1, 1999. These *Standards* cover single-family and low-rise residential buildings (occupancy groups R1 and R3) including:

- All single-family dwellings of any number of stories
- All duplex (two-dwelling) buildings of any number of stories
- All multi-family buildings with three or fewer habitable stories
- All occupancy group R2 buildings with three or fewer habitable stories
- Additions to all the above buildings

The applicable design manual for those buildings is the *Residential Manual for Compliance with the Energy Efficiency Standards for Low-Rise Residential Buildings.*

Copies of the compliance manuals and other relevant publications may be obtained by contacting the Energy Commission (see Appendix F).

2.1.2 Basic Scope and Application Concepts

The following discussion explains the definitions of the key terms for understanding the scope and application of the *Standards*. In most cases, a careful reading of these definitions will resolve questions of interpretation. These definitions are located in Section 101 of the *Standards;* italicized words below indicate the wording taken verbatim from that Section.

A. Conditioned Space Definitions

Building *is any structure or space for which a permit is sought.* By this definition, a building is not necessarily a complete physical structure. For the *Standards,* a building in this sense can be a lighting system recircuiting project, because this would require an electrical permit.

Conditioned Floor Area (CFA) *is the floor area (in square feet) of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces of exterior walls enclosing the conditioned space.* Once the spaces that are directly or indirectly conditioned are identified, then it is possible to calculate the conditioned floor area of the building. This number is used for various calculation purposes in complying with the *Standards.* The CFA is generally calculated from dimensions on the floor plans of the building. It is measured from the outside surfaces of exterior walls, with the dimensions taken at floor level. This definition helps mitigate any complexity from sloping walls, bay windows and other unique building details.

Conditioned Space *is space in a building that is either directly conditioned, indirectly conditioned or semi-conditioned.* In most circumstances it is obvious whether a space is conditioned or semi-conditioned. There are, however, special circumstances that require a closer look at the definitions of directly and indirectly conditioned space.

Directly Conditioned Space *is an enclosed space that is provided with wood heating, is provided with mechanical heating that has a capacity exceeding 10 Btu/(hr-sf), or is provided with mechanical cooling that has a capacity exceeding 5 Btu/(hr-sf), unless the space conditioning system is designed and thermostatically controlled to maintain a process environment temperature less than 55°F or to maintain a process environment temperature greater than 90°F for the whole space that the system serves, or unless the space conditioning is designed and controlled to be incapable of operating at temperatures above 55°F or incapable of operating at temperatures below 90°F at design conditions.* This definition contains several key ideas central to the *Standards*. First, mechanically heated or mechanically cooled space (discussed below) may be conditioned (i.e., it does not have to be both heated and cooled). Second, it depends on how much heating or cooling is provided to determine if the space is directly conditioned. It is not uncommon for an otherwise unheated space (such as a warehouse) to have a small area with a unit heater, such as a desk on the loading dock. This usually does not make the entire structure a heated space (see also semi-conditioned space). The total quantity of heating provided to the space has to exceed 10 Btu/(hr-sf). Similar logic applies to a mechanical cooling system; if it provides more than 5 Btu/(hr-sf), it means the space is directly conditioned. Third, it matters at what the temperature the space is controlled. Many spaces, such as refrigerated warehouses, are conditioned but are deliberately kept at very hot or cold temperatures. The space conditioning is not for human comfort but to serve the needs of some process, such as preventing vegetables from spoiling. If the space conditioning system is specifically designed and operated to maintain a temperature that is not within the range of 55°F through 90°F and is thermostatically controlled not to operate within this temperature range, then the space is not directly conditioned, and is therefore exempt from the *Standards*. NOTE: the reference to wood heating in the above *Standards* definition of **Directly Conditioned Space** pertains to low-rise residential buildings only, Section 100(a)3.B. Nonresidential building with wood heat are semi-conditioned.

Example 2-2: Direct Heating

Question
If a space were 1,000 sf, how large would the heating system have to be to make the space directly conditioned?
Answer
The heating system would have to be larger than 10 Btu/(hr-sf) x 1,000 sf = 10,000 Btu/hr output to meet the definition of directly conditioned space.

Example 2-3

Question
A water treatment plant has a heating system installed to prevent pipes from freezing. The heating system exceeds 10 Btu/(hr-sf) and operates to keep the space temperature from falling below 50°F. Is this plant directly conditioned?
Answer
Not if the heating system is sized to meet the building load at 50°F and is thermostatically controlled to prevent operating temperatures above 50°F. The definition of directly conditioned space excludes spaces that have space conditioning designed and controlled to be incapable of operating at temperatures above 55°F at design conditions. Under these conditions, the space is not directly conditioned.

Example 2-4: Direct Cooling

Question
A manufacturing facility will have space cooling to keep the temperature from exceeding 90°F. If the thermostat will not allow cooling below 90°F is this facility directly conditioned?
Answer
No, this facility is not directly conditioned. The definition of directly conditioned space excludes spaces where the space conditioning system is designed and controlled to be incapable of operating at temperatures below 90°F at design conditions.

Enclosed Space *is space that is substantially surrounded by solid surfaces.* Spaces that are not enclosed are spaces that are open to the outdoors, such as covered walkways, parking structures that are open or have fenced mechanical enclosures.

Entire Building *is the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all existing conditioned and unconditioned space within the structure.* This definition affects lighting compliance within the complete building method.

Habitable Story *is a story that contains space in which humans may work or live in reasonable comfort, and that has at least 50 percent of its volume above grade.* This definition is important in distinguishing between high-rise and low-rise residential buildings, which are covered by different *Standards* and are described in separate *Manuals*. Basement floors with more than 50 percent of their volume below grade are not counted as habitable stories regardless of their actual use. In buildings on sloping ground, the calculation of volume below grade can become cumbersome, but for most buildings it will be obvious whether the floor is at least 50 percent above grade.

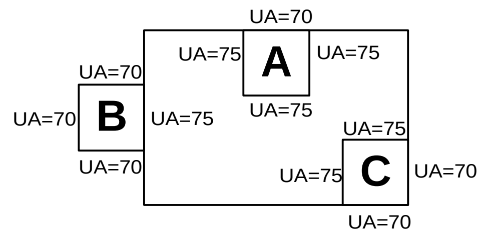
Indirectly Conditioned Space *is enclosed space including, but not limited to, unconditioned volume in atria, that (1) is not directly conditioned space; and (2) either (a) has an area-weighted heat transfer coefficient to directly conditioned space exceeding that to the outdoors or to unconditioned space, or, (b) is a space through which air from directly conditioned spaces is transferred at a rate exceeding 3 air changes per hour.* This definition is important because the *Standards* treat indirectly conditioned space the same as conditioned space; in other words, indirectly conditioned spaces must meet the requirements of the *Standards*. As a guide, professional judgment should be exercised when determining whether a space is *indirectly conditioned*, especially as relates to door placement in the space. When an enclosed space that is not directly conditioned has openings only into a conditioned space, it should be considered indirectly conditioned. Likewise, when an enclosed space that is not directly conditioned has openings only to the outdoors, it should be considered to be unconditioned. When enclosed spaces that are not directly conditioned have openings both to the outdoors and to conditioned spaces, an evaluation of relative heat transfer and air change rate (UA) (see Example 2-5) should be used to determine the status of the space. A typical example of an indirectly conditioned space might be the stairwell of a high-rise office building. The first part of the definition is that it not be directly conditioned. This is not uncommon in stairwells. The second part of the definition is that it be provided with space conditioning energy from a space that is directly conditioned. This can be done one of two ways. The first is by conduction heat transfer. If heat is transferred in from directly conditioned space (e.g., through the walls of the stairwell) faster than it is transferred out to the unconditioned surroundings, then the space is considered to be indirectly conditioned (see Example 2-5). The second way is for the space to be ventilated with air from directly conditioned spaces. For example, if exhaust hoods draw air through a kitchen from the dining room at a rate exceeding three air changes per hour, then the kitchen will be considered indirectly conditioned space.

Example 2-5: Indirectly Conditioned Space (by conduction)

Question

The accompanying sketch shows a building with three unconditioned spaces (none has a direct source of mechanical heating or cooling). The air transfer rate from the adjacent conditioned spaces is less than 3 air changes per hour. The area weighted heat transfer coefficients of the walls (UA) are shown on the sketch. The roof/ceiling area weighted heat transfer coefficients (UA) for each of the three unconditioned spaces is 90 Btu/Hr -°F.

Are any of these spaces indirectly conditioned?



Answer

Because the air change rate is low, we evaluate each space on the basis of heat transfer coefficients through the walls and roof. It is further assumed that the floors are adiabatic. Therefore, the heat transfer will be proportional to the area weighted heat transfer coefficients of the walls and roof/ceilings.

SPACE A: *The area weighted heat transfer coefficient to directly conditioned space is 3 x (75 Btu/Hr-°F) = 225 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is 70 Btu/Hr-°F + 90 Btu/Hr-°F = 160 Btu/Hr-°F. Since the heat transfer coefficient from Space A to the conditioned space is greater than heat transfer coefficient from Space A to outside, Space A is considered indirectly conditioned.*

SPACE B: *The area weighted heat transfer coefficient to directly conditioned space is 75 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (3 x 70 Btu/Hr-°F) + 90 Btu/Hr-°F = 300 Btu/Hr-°F. Since the heat transfer coefficient from Space B to the conditioned space is less than the heat transfer coefficient from Space B to outside, Space B is considered unconditioned.*

SPACE C: *The area weighted heat transfer coefficient to directly conditioned space is (2 x 75 Btu/Hr-°F = 150 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (2 x 70 Btu/Hr-°F) + 90 Btu/Hr-°F = 230 Btu/Hr-°F. Since the heat transfer coefficient from Space C to the conditioned space is less than the heat transfer coefficient from Space C to outside, Space C is considered unconditioned.*

Mechanical Cooling *is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space. In nonresidential, high-rise residential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling (see also "directly conditioned space").* For buildings covered by this *Manual,* evaporative cooling is not considered mechanical cooling. This means, for example, that a warehouse with only evaporative coolers does not meet the definition of mechanical cooling. Nonresidential buildings with evaporate cooling are a semi-conditioned space.

Mechanical Heating *is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy from depletable sources to directly conditioned space.* If the source of the heat is a nondepletable source, then the system is not considered mechanical heating. Nondepletable sources would include solar collectors, geothermal sources, and heat recovered from a process, such as refrigeration chillers.

Newly Conditioned Space *is any space being converted from unconditioned to directly conditioned or indirectly conditioned space, or any space being converted from semi-conditioned to directly conditioned or indirectly conditioned space. Newly conditioned space must comply with the requirements for an addition.*

Process *is an activity or treatment that is not related to the space conditioning, lighting, service water heating, or ventilating of a building as it relates to human occupancy.*

Semi-Conditioned Space *is an enclosed nonresidential space that is provided with wood heating, cooling by direct or indirect evaporation of water, mechanical heating that has a capacity of 10 Btu/(hr ft^2) or less, mechanical cooling that has a capacity of 5 Btu/(hr ft^2) or less, or is maintained for a process environment as set forth in the definition of DIRECTLY CONDITIONED SPACE.* Buildings that are semi-conditioned must meet the lighting requirements of the *Standards* (see Chapter 5). No mechanical or envelope compliance is required as long as the building is maintained as a semi-conditioned space.

Space Conditioning System *is a system that provides either collectively or individually heating, ventilating, or cooling within or associated with conditioned spaces in a building.* The *Standards* apply to conditioned space, and they govern the space conditioning systems that provide the conditioning for those spaces.

Unconditioned Space *is enclosed space within a building that is not directly conditioned, indirectly conditioned or semi-conditioned space.* Unconditioned space is not covered by the *Standards*

B. Occupancies

High-Rise Residential *is a building, other than a hotel/motel, of occupancy group R-1 with four or more habitable stories.* UBC Occupancy Group R-1 includes apartment houses, convents and monasteries (accommodating more than 10 persons). (See definition of Unconditioned Space above). If a building has four or more habitable stories, any residential occupancy in the building is considered high-rise residential, regardless of the number of stories that are residential.

Example 2-6: High-Rise Residential

Question

A four-story building has one floor retail, two floors are offices and the fourth floor is residential (as defined in the UBC). Is the residential space high-rise or low-rise?

Answer

It is a high-rise residential space. Even though there is only one floor of residential occupancy, the building has four habitable stories, making it a high-rise building.

Hotel/Motel *is a building or buildings incorporating six or more guest rooms or a lobby serving six or more guest rooms, where the guest rooms are intended or designed to be used, or which are used, rented, or hired out to be occupied, or which are occupied for sleeping purposes by guests, and all conditioned spaces within the same building envelope. Hotel/motel also includes all conditioned spaces that are (1) on the same property as the hotel/motel, (2) served by the same central HVAC system as the hotel/motel, and (3) integrally related to the functioning of the hotel/motel as such, including, but not limited to, exhibition facilities, meeting and conference facilities, food service facilities, lobbies and laundries.* A key part of this definition is that the hotel/motel includes all spaces within the same building envelope as the lobby or the guest rooms. This is because hotel/motel buildings are generally multi-purpose facilities. They may include such diverse spaces as restaurants, auditoriums, retail stores, offices, kitchens, laundries and swimming pools. All are treated as hotel/motel spaces.

This concept extends to other buildings associated with the hotel/motel that pass the three tests:

- Same property
- Same central HVAC system
- Integrally related to the hotel/motel

Refer also to Section 6.2 for a complete discussion of hotel/motel compliance issues.

Mixed Occupancies The *Standards* apply to mixed occupancies in the same way they apply to single occupancy buildings. The low-rise residential *Standards* apply to applicable occupancies; the nonresidential *Standards* apply to appropriate occupancies. If these two types occur in the same building, the building must be treated as two separate buildings for purposes of energy compliance, with each part meeting its applicable requirements. An exception provides that if one occupancy makes up 90% of the building, the entire building may comply with the provisions of the dominant occupancy. The mandatory measures for the actual occupancy will apply. This subject is discussed and illustrated in greater detail in Section 2.2.6C.

Other Occupancy Definitions: There are over 35 additional occupancy definitions in the *Standards*. They are used primarily to assign lighting area categories. Refer to the Glossary, Appendix G, for these definitions. All are found alphabetically under "Occupancy Type."

2.2 APPLICATION SCENARIOS

This section illustrates the use of the application rules in typical building situations.

2.2.1 Unconditioned Space

Unconditioned space is neither directly nor indirectly nor semi-conditioned, as defined in the previous section. Unconditioned space is not subject to the *Energy Efficiency Standards*. Some typical examples of spaces that may be unconditioned:

- Parking structures
- Automotive workshops
- Covered entry courts or walkways
- Outdoor dining areas
- Greenhouses
- Loading docks
- Mechanical/electrical equipment rooms

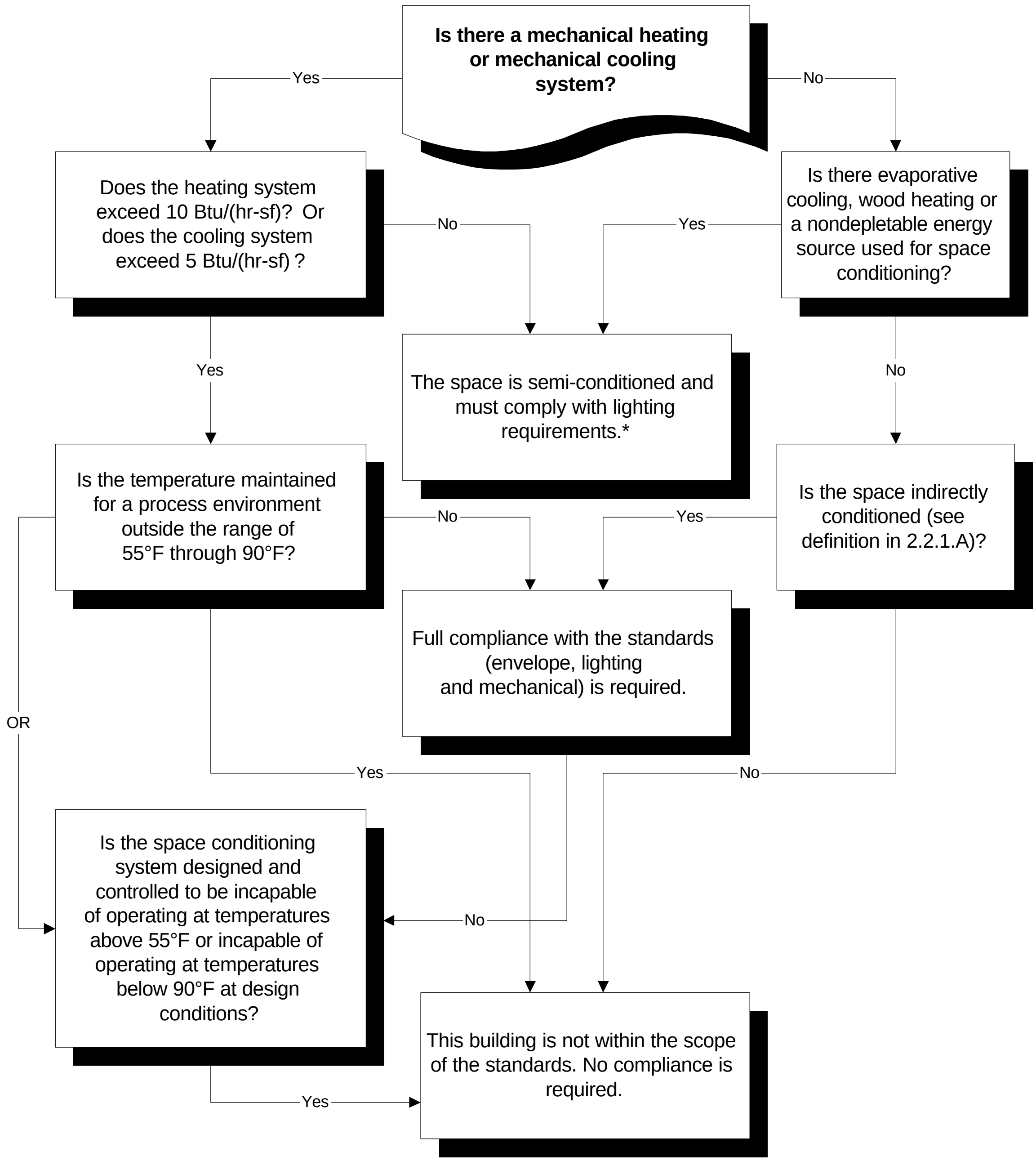
Keep in mind that these kinds of spaces are not always unconditioned. The specifics of each case must be determined. See the flowchart in Figure 2-1 to determine whether a space is unconditioned, conditioned, or semi-conditioned.

2.2.2 Newly Conditioned Space

While unconditioned buildings do not have to comply with the *Standards,* it is not simple to change an unconditioned building to a conditioned building.

When previously unconditioned space becomes conditioned, the space is then considered an "addition" and all the building's components must then comply as if it were a new building (see Section 2.2.5 below and *Standards* Section 149(a).) If conditioning an existing building results in a space that is semi-conditioned, the *Standards* do not apply.

Figure 2-1: Type of Conditioned Space and Scope of Compliance



*In an alteration, if space conditioning is added to an existing unconditioned building, resulting in it being semi-conditioned, no requirements apply. If space conditioning is added to an existing unconditioned building, resulting in it becoming conditioned, full compliance is required.

This situation has potentially significant construction and cost implications. For example, if an unconditioned warehouse is upgraded with a heating system thus becoming conditioned space, the building envelope must comply with the current envelope requirements and the lighting system must be brought into conformance with the current lighting requirements, including mandatory wiring and switching. If the envelope has large windows, it is conceivable that some would have to be blocked off. If the lighting system is inefficient, fixtures might have to be removed and new, more efficient fixtures installed.

This requirement can cause difficulty when an owner of a building seeks exemption from complying with the *Standards* by erecting a shell with no plans to condition it. For example, the owner of an office building obtains a permit for the structure and envelope, but wishes to leave the space conditioning and lighting improvements to the tenants. If that owner claims unconditioned status for that building, the owner does not have to demonstrate compliance with the envelope requirements of the *Standards.* As soon as the tenant applies for a permit to install the HVAC equipment, however, the envelope and any existing lighting in the shell must then be brought into full compliance. (This is the only circumstance when systems, other than those subject to the current permit application, fall under the *Standards.*) If the building was initially designed in a way that makes this envelope compliance difficult, the building envelope may require expensive alterations to bring it into compliance. A similar situation could occur with the lighting system if it is installed in the “unconditioned” building.

Many building departments require the owner to sign an affidavit at the time of the initial building permit for the shell, acknowledging the potential difficulties of future envelope or lighting compliance. For a discussion of the compliance procedures associated with this practice, refer to Sections 3.3, 4.3 and 5.3.

To minimize *Standards* compliance difficulties, the recommended practice is to demonstrate energy compliance at the time the envelope is built, and to do the same for the lighting system.

2.2.3 New Construction in Existing Buildings

Alterations, tenant improvements, and repairs are new construction in an existing building. For example, the base building has been constructed, but the individual tenant spaces have not been completed. Tenant improvements can include work on the envelope, the mechanical or the lighting systems. Whatever the case, the system or systems being installed are considered to be new construction, and must comply with some or all of the current *Standards*, depending on the extent of the changes (see following sections).

The only circumstance when systems other than those subject to the current permit application come under scrutiny is when the tenant improvement results in the conditioning of previously unconditioned space. Refer to the previous Section 2.2.2 for a complete discussion of this situation.

2.2.4 Alterations to Occupied Spaces

Alteration *is any change to a building’s water heating system, space conditioning system, lighting system, or envelope that is not an addition.* Alterations or renovations to existing conditioned spaces have their own set of rules for energy compliance. They are covered in a separate section of the *Standards,* Section 149(b). (Additions are discussed in Section 2.2.5.)

In summary, the alteration rules are:

1. The *Standards* apply only to those portions of the systems being altered; untouched portions need not comply with the *Standards*.

2. If an envelope or lighting alteration increases the energy use of the altered systems, the alteration must comply with the current *Standards*.

3. Alterations must comply with the mandatory measures for the changed components.

4. New systems in the alteration must comply with the current *Standards*.

5. In an existing semi-conditioned building, altered lighting must meet mandatory measures for the changed lighting component. Alterations that increase the connected lighting load or replace more than 50% of the lighting fixtures must meet current *Standards*.

6. In an existing, unconditioned building where evaporative cooling is added (making the building semi-conditioned) the existing unaltered envelope and lighting do not need to be brought into compliance with current *Standards*.

The effect of these rules is that, in most cases the existing systems (envelope and lighting) set the standard for the altered systems. For example, if the existing lighting system is changed but does not increase the connected lighting load, does not replace more than 50% of fixtures, but meets the applicable mandatory measures, it complies. The same holds true for changes to the envelope: if the overall heat loss or heat gain is not increased and it meets its applicable mandatory measures, then it complies. Mechanical system alterations are governed primarily by the mandatory measures.

The alternative alteration rule is to make changes to the existing building so that the entire building (existing and alteration) complies with the performance approach of the current *Standards*. Keep in mind that, under the performance approach, credit is given only for systems that are actually changed in the current construction process (see Section 6.1 and *Standards* Section 149(b)).

Example 2-7: New Window

Question

An owner wants to add a new window in an old building. This will increase the glazing area. How do the Standards apply?

Answer

Envelope alterations require demonstrating that the overall heat gain and heat loss are not increased. However, the heat gain calculation considers only glazing (i.e., only measures which offset the heat gain, such as tinting, are considered), making it is difficult to achieve compliance with this option.

The option is also available to meet the current requirements for the component being altered. This means meeting the glass U-value, percentage, and shading requirements of the current standards. For example, a building in Climate Zone 9 would require a window U-value <1.23, relative solar heat gain of 0.62 (south, east and west) or 0.82 (north), and the total area of fenestration (existing and new) is limited to 40% of the gross exterior wall area (considering only the altered wall of the permitted space).

Example 2-8: New Lighting Fixture

Question

A building owner wants to change existing lighting fixtures with new ones. Do the Standards restrict the change in any way?

Answer

If more than 50% of the fixtures are replaced, or the connected load is increased, the Standards will treat this as a new lighting system that must comply with Section 146. Any applicable mandatory requirement affected by the alteration applies, and the mandatory switching requirements would apply to the improved system if the circuiting were altered. Title 20 Appliance Efficiency Regulations requirements for ballasts would also apply. See Section 5.2.1.

Example 2-9: New Interior Partitions

Question
A building owner wants to rearrange some interior partitions and re-position the light fixtures in the affected rooms. Do the energy Standards apply to the work?
Answer
Each of the newly arranged rooms must have its own light switches. Since there is no change in the connected lighting load or the exterior envelope, only the mandatory light switching requirements would apply. Refer to Section 5.2.1 for more detail on these requirements.

Example 2-10: Altered Duct Work

Question
A building owner wants to re-arrange some duct work and add some additional fan coils to an existing HVAC system to improve comfort. Do the energy Standards apply to the work?
Answer
There would be no change in the load on the system nor any increase in its overall capacity,so the Standards would not apply to the central system. Only the duct construction requirements apply to altered ducting (see Section 4.2.1J).

Example 2-11: Chiller Replacement

Question
A building owner wants to replace an existing chiller. No other changes will be made to the HVAC system. Do the Standards restrict the change in any way?
Answer
The mandatory efficiency requirements would govern the efficiency of the new chiller (see Section 4.2.1A). The other parts of the system are unchanged and therefore unaffected by the Standards.

Example 2-12: Adding a Mezzanine

Question
A building owner has a high ceiling space and wants to build a new mezzanine space within it. There will be no changes to the building envelope or to the central HVAC system. There will be new lighting installed. How do the Standards apply?
Answer
Since a mezzanine does not add volume, it is an alteration, not an addition. The existing systems are not affected unless they are altered. The new lighting must comply with all requirements of the standards. The envelope is unchanged, so there are no requirements for it. The mechanical system duct work is simply extended without increase in system capacity, so only the duct construction and insulation requirements apply.

2.2.5 Additions

Addition *is any change to a building that increases conditioned floor area and conditioned volume.*

Additions involve either the construction of new, conditioned space and conditioned volume, or the installation of space conditioning in a previously unconditioned space. The mandatory measures, and either the prescriptive or the performance requirements apply. The heating, lighting, envelope, and water heating systems of additions are treated the same as for new buildings. The only exception to this is if the existing systems are simply extended into the addition (*Standards* exception to Section 149(a)). Refer above to Section 2.2.2 for further discussion of previously unconditioned space.

There are three options for the energy compliance of additions under the *Standards*:

Option 1: Treat the addition as a stand-alone building with adiabatic walls to conditioned space (Section 149(a)1. and (Section 149(a)2.B.1.). This option can employ either the prescriptive or the performance approach.

Adiabatic means the common walls are assumed to have no heat transfer between the addition and the adjacent conditioned space, and are ignored entirely.

Option 2: Combine the existing building with the addition (Section 149(a)2.B.2.). This option only works with the performance approach. It uses the custom budget approach to develop an energy budget for the existing building and a standard version of the addition. These combine into a total building energy budget. The combined building is then modeled as proposed. If it meets the budget, the addition complies.

This option will generally work to ease the energy requirements of the addition only if there are energy improvements to the existing building. It does allow the designer to make a relatively energy inefficient addition comply.

Option 3: The existing structure combined with the addition can be shown to comply as a whole building with all requirements of the current *Standards* for envelope, lighting and mechanical.

Example 2-13: Energy Inefficient Addition

Question

A restaurant adds a greenhouse-style dining area with large areas of glazing. It is directly conditioned space. How can it comply with the Standards?

Answer

Because of its large glass area, it will not comply on its own. By making substantial energy improvements to the existing building (lighting, mechanical or envelope), it is possible for the combined building to comply. The performance approach would be used to model the combined existing/new building.

2.2.6 New Buildings

A. Speculative Buildings - Known Occupancy

Speculative buildings of known occupancy are commonly built by developers. For example, if a strip shopping center or an office building were built on speculation, the owner would usually know the ultimate occupancy of the space but might not know the actual tenants. For this type of building, the owner could take responsibility for any or all of the major components by simply building and showing energy compliance for the envelope, and leaving the lighting and HVAC improvements to the tenants (or the project could include the other systems as well).

Because compliance may be demonstrated for each component separately, the owner can simply demonstrate that the systems being built meet the *Standards*. The remaining construction and *Standards* compliance work can be dealt with as each tenant obtains building permits for work in their individual spaces (see Section 2.2.3).

Often, the developer will seek to minimize first cost by delaying compliance and construction of as much of the project as possible. While this can be done under the *Standards,* there are two disadvantages:

1. If all *Standards* compliance is deferred by declaring the building to be unconditioned, the owner needs to understand the potential problems that could arise later when the building is conditioned. Refer to the discussion in Section 2.2.2 above.

2. If only the envelope or lighting systems are shown to comply, the owner loses the opportunity to apply the performance approach to the entire building and so to make trade-offs between systems to optimize the cost-effectiveness of the design.

B. Speculative Buildings - Unknown Occupancy

Speculative buildings are often built for which the ultimate occupancy is determined at the time of leasing and not during construction of the building shell. The structure, for example, could eventually be used as an office, a warehouse, a restaurant or retail space. Because the *Standards* treat these occupancies in a similar fashion, the fact that the ultimate occupancy is unknown is not a significant problem. The major items affected by the ultimate occupancy have to do with lighting and ventilation requirements.

The major problem that can occur with this type of building comes when the owner elects to declare it as an unconditioned building and defer *Standards* compliance until such time as a tenant installs mechanical space conditioning equipment. Refer to Section 2.2.2 for a complete discussion of this problem.

C. Mixed Use Buildings

Because the *Standards* are different for residential and nonresidential buildings, and because mixed use buildings occasionally include more than one type of occupancy, there is potential for confusion in application. The *Standards* address these circumstances regarding mixed use buildings:

1. **Minor Occupancy** (exception to Section 100(e)). If the minor occupancy or occupancies occupy less than 10% of the total conditioned floor area, then they are treated as if they were of the major occupancy. The mandatory measures applicable to the minor occupancy, if different from the major occupancy, would still apply.

Example 2-14: Minor Occupancy

Question
A 250,000 sf high-rise office building includes a small 500 sf apartment for use by visiting executives. This is clearly a residential occupancy, so is the apartment required to meet the residential requirements of the Standards?
Answer
No. It occupies less than 10% of the total conditioned floor area, so it is a minor occupancy and may be treated as part of the office occupancy. Residential mandatory measures apply.

2. **Different Nonresidential Occupancies**. When both of these occupancies fall under the nonresidential *Standards*, they would be dealt with together under the same compliance process. Although the occupancies may have different envelope and lighting requirements, these are not so different as to require special compliance procedures.

3. **Hotel/motel and Nonresidential Occupancies.** A hotel/motel with guest rooms, restaurants, sports facilities and other nonresidential occupancies is defined as a hotel/motel occupancy (see Section 2.1.2B and *Standards* Section 101(b)). The only variance is that the guestroom envelope and lighting and HVAC control requirements are different.

4. **Mixed Low Rise Residential and Nonresidential Occupancies.** These occupancies fall under different sets of *Standards,* they are considered separately. Two compliance submittals must be prepared, each using the calculations and forms of its respective *Standards*.

D. Semi-Conditioned Buildings

Some buildings such as warehouses may fall into the category of a semi-conditioned building (see 2.2.1 to determine if a space is unconditioned or semi-conditioned). The *Standards* require only lighting compliance in buildings that are semi-conditioned.

2.2.7 Change of Occupancy

A change of occupancy alone does not require any action under the energy *Standards*. If changes are made to the building, however, then the rules for alterations or additions apply (see Sections 2.2.4 and 2.2.5).

If the change in occupancy involves converting from a residential to a nonresidential occupancy or vice versa (changes defined by UBC occupancy definitions), then the *Standards* applicable to the new occupancy would govern any alterations made to the building. For example, if a home is converted to law offices, and a new lighting system is installed, the nonresidential lighting requirements would apply. If a new HVAC system is installed, all the nonresidential HVAC requirements, would have to be met.

If no changes are proposed for the building, it is advisable to consider the ventilation requirements of the new occupancy. For example, if a residence is converted to a hair salon, the ventilation rates of the building should be considered. With new sources of indoor pollution, the existing residential ventilation rates would likely not be adequate for the new uses.

2.2.8 Repair

A Repair *is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. Repairs shall not increase the pre-existing energy consumption of the required component, system, or equipment.*

Chapter 2 Index

A

Addition · 11, 12
Alterations · 1, 9, 10
Altered Duct Work · 11
Appliance Efficiency Regulations · 10
Application · 1, 3
Application Scenarios · 1
Assembly · 2

B

Building · 2, 3, 4

C

Change of Occupancy · 1, 14
Churches · 2
Climate · 10
Climate Zone · 10
Commercial · 2
Compliance · 2, 8
Concepts · 1, 3
Conditioned Floor Area · 3
Conditioned Space · 1, 3, 4, 5, 6, 7, 8
Cooling · 4, 6

D

Directly Conditioned · 3
Directly Conditioned Space · 3
Duct Work · 11

E

Enclosed Space · 4
Entire Building · 4
Existing Buildings · 1, 9

F

Floor Area · 3

G

Greenhouses · 7

H

Heating · 4, 6
High-Rise Residential · 2, 6
Hotel/Motel · 7

I

Indirectly Conditioned Space · 4, 5
Industrial · 2
Interior Partitions · 11

K

Known Occupancy · 1, 12

L

Lighting · 10
Low-Rise Residential · 2

M

Mechanical Cooling · 6
Mechanical Heating · 6
Mezzanine · 11
Minor Occupancy · 13
Mixed Occupancies · 7
Mixed Use Buildings · 13

N

New Buildings · 1, 12
New Construction · 1, 9
New Interior Partitions · 11
New Lighting Fixture · 10
Newly Conditioned Space · 6, 7

O

Occupancy · 1, 2, 6, 7, 12, 13, 14
Offices · 2

P

Process · 6

R

Repair · 1, 14
Residential Manual · 2
Residential Standards · 2
Retail · 2

S

Schools · 2
Semi-Conditioned Space · 6
Space Conditioning · 6
Space Conditioning System · 6
Speculative Buildings · 12, 13
State Historic Building Code · 2

T

Tenant · 9
Theaters · 2

U

UBC · 2, 6, 14
Unconditioned Space · 1, 6, 7
Uniform Building Code Occupancy Groups · 2
Unknown Occupancy · 1, 13
U-value · 10

ENV

Chapter 3: Building Envelope

3.0 CHAPTER OVERVIEW

This chapter discusses the requirements of the *Energy Efficiency Standards* as they apply to the building envelope (walls, roofs, floors, windows, skylights, etc.). It addresses questions a building envelope designer, plan checker or inspector needs answered. Additional information is found in Chapter 2: Scope and Application and Chapter 6: Special Topics.

Chapter Contents

3.0 Chapter Overview 3-1

3.1 Introduction 3-2

3.1.1 Envelope Compliance Approaches 3-2

A: Prescriptive Approach 3-2

B: Performance Approach 3-2

3.1.2 Basic Envelope Concepts 3-3

A: Definitions 3-3

B: Insulation R-value 3-7

C: Overall Assembly U-value 3-7

D: Wood Frame U-values 3-7

E: Metal Frame U-values 3-9

F: Masonry U-values 3-10

G: Heat Capacity 3-11

H: Fenestration U-values 3-12

I: Solar Heat Gain Coefficient 3-13

J: Relative Solar Heat Gain 3-13

3.2 Envelope Design Procedures 3-15

3.2.1 Mandatory Measures 3-15

A: Doors, Windows and Skylights 3-15

B: Joints and Openings 3-16

C: Insulation Materials 3-16

D: Demising Walls 3-16

3.2.2 Prescriptive Component Approach 3-17

A: Exterior Roofs and Ceilings 3-17

B: Exterior Walls 3-18

C: Demising Walls 3-18

D: Exterior Floors and Soffits 3-19

E: Windows 3-19

F: Skylights 3-21

G: Exterior Doors 3-22

3.2.3 Prescriptive Overall Approach 3-22

A: Overall Heat Loss 3-24

B: Overall Heat Gain 3-26

3.2.4 Performance Approach 3-29

A: Modeling Envelope Components 3-29

3.2.5 Alterations 3-30

3.3 Envelope Plan Check Documents 3-30

3.3.1 ENV-1: Certificate of Compliance 3-31

3.3.2 ENV-2: Envelope Component Method 3-39

3.3.3 ENV-2: Overall Envelope Method 3-43

3.3.4 ENV-3: Metal Framed Assembly 3-53

3.3.5 ENV-3: Masonry Wall Assembly 3-56

3.3.6 ENV-3: Wood Frame Assembly 3-59

3.4 Envelope Inspection 3-62

The Introduction section (3.1) explains the basic envelope compliance approaches and provides a tutorial on many of the concepts necessary to an understanding of the envelope requirements. The Envelope Design Procedures section (3.2) discusses the requirements of the *Standards* as they concern a designer. The Envelope Plan Check Documents section (3.3) explains the compliance forms and the information, which must be included on the plans by the designer prior to being checked by the building department.

3.1 INTRODUCTION

The design of the building envelope is generally within the domain of an architect, although it may be done by a contractor, an engineer, or some other person. The designer is responsible for making sure that the envelope design complies with the *Standards*. Likewise, the building department is responsible for making sure that the envelope is designed and built in conformance with the *Standards*. This chapter is addressed to both the designer and the building department, and to the related specialists who participate in the design and construction of the building envelope.

3.1.1 Envelope Compliance Approaches

The envelope requirements contain more than one approach to compliance in order to allow flexibility to accommodate the wide variety of nonresidential buildings. The characteristics, advantages and disadvantages of each method are introduced in this Section. These requirements are in addition to the envelope mandatory measures, which apply regardless of the compliance approach (Section 3.2.1).

A. Prescriptive Approach (§143)

Envelope Component Approach vs. Overall Envelope Approach

Under the prescriptive approach there are two alternatives for envelope compliance: the Envelope Component Approach and the Overall Envelope Approach.

Envelope Component Approach (Section 143(a)) is the simpler and more direct of the two prescriptive compliance approaches. It consists of a specific requirement for each envelope component: roofs and ceilings, exterior walls, demising walls, external floors and soffits, windows, and skylights.

There are no trade-offs between components. If all the requirements are met, the envelope complies. If even one component does not meet its individual requirement, the envelope does not comply.

Under the Envelope Component Approach, each opaque assembly has to meet a minimum insulation level. Each glazing component has to meet insulating and solar heat gain coefficient (SHGC) values, and there is an upper limit on glazing area. If these requirements are met, the building will comply with the *Standards.* See Section 3.2.2 for a more complete discussion of the Envelope Component Approach.

Overall Envelope Approach (Section 143(b)) treats envelope components as a group. This offers the ability to make trade-offs between envelope components, which is the principal advantage of this approach.

The Overall Envelope Approach uses two measures of envelope performance: the overall heat loss and the overall heat gain. The overall heat loss is a measure of the insulating quality of all the envelope components together, including both opaque and glazing surfaces. The overall heat gain is a measure of the insulation quality of the envelope component and the solar heat gain qualities of the glazing and envelope.

The *Standards* for both heat gain and heat loss of the envelope are calculated using the insulation and solar heat gain coefficient values from the Envelope Component Approach, and applying them to the building's envelope surface areas, as designed (with some limits on glazing area). The proposed design's overall heat loss and heat gain are calculated based on the installed insulation and glazing performance. If the proposed heat loss and heat gain are no higher than the standard heat loss and heat gain, then the envelope complies. See Section 3.2.3 for a more complete discussion of the Overall Envelope Approach.

B. Performance Approach (§141)

The other option for envelope compliance is the Performance Approach. It may be used for either envelope-only compliance or may include lighting and mechanical system compliance if permitted at the same time. When the performance approach is used for the envelope only, the computer model deals with the energy efficiency of the entire envelope under both heating and cooling conditions. This means that trade-offs can be made between all envelope components. The computer analysis is much more sophisticated and can account for more subtle energy effects due to surface orientation and hourly changes in the outside temperature. If the envelope compliance is combined with other parts of the building, then more trade-offs can be made, such as increasing envelope efficiency in order to allow more lighting power or a less efficient mechanical system. See Sections 3.2.4 and 6.1 for a more complete discussion of the performance approach.

3.1.2 Basic Envelope Concepts

In order to understand the particulars of each of these approaches, several key definitions and energy concepts must be presented. In addition, before proceeding to the discussion below, the reader should be familiar with the various conditioned space definitions (see Section 2.1.2A).

A. Definitions (§101(b))

Atrium *is an opening through two or more floor levels other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning, or other equipment which is enclosed space and not defined as a mall.* The definition of an atrium is significant because of the skylight area requirements. The key concept is that the atrium is an opening through floor levels, not counting openings needed for equipment. Malls are not considered as atria. The skylight requirements are different when the atrium is over 55 feet high. According to the UBC, an atrium over 55 feet high must have a mechanical ventilation system (particulars defined in the UBC), so the higher skylight allowances for atriums only apply when the ventilation system is required. In questionable cases, the determination of atrium height will be made by the building department, and will follow UBC guidelines.

Demising Partitions *are barriers that separate conditioned space from enclosed unconditioned space.* The only difference between an exterior partition and a demising partition is that the demising partition has enclosed unconditioned space on one side, rather than outdoor space. The demising partition could adjoin, for example, an unconditioned warehouse, an enclosed garage, or an unconditioned vestibule. The distinction between exterior and demising walls is made because demising walls have their own requirements and they are not treated the same way as exterior partitions in the energy calculations.

Demising Wall *is a wall that is a demising partition.* A wall is the only case where a demising partition is treated differently from an exterior partition (there are special insulation requirements (Sections 143(a)3 and 118(e)). Glazing area in demising walls is not limited (Sections 141(a) and 143(a)5A).

Display Perimeter *is the length of an exterior wall in a* B, F-1 or M *occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk.* This generally refers to retail display windows, although other occupancies such as offices can also have a display perimeter. Public sidewalks are accessible to public at large (no obstructions, limits to access, or intervening non-public spaces). The display perimeter is used for a special calculation of window area (Section 143(a)5A). Demising walls are not counted as part of the display perimeter.

Effective Apperture (See Chapter 5).

Exterior Door *is a door through an exterior partition.* The exterior door area is used only in calculating the gross exterior wall area; there are no R-value, U-value or area requirements for exterior doors (Section 143(a)7). Note that if the door has glazing in excess of one-half of the door area, that glazing is a window or a skylight (depending on slope). See discussion of **Window Area** below for the measurement of glazing area in doors.

Exterior Floor/Soffit *is a horizontal exterior partition, or a horizontal demising partition, under conditioned space.* It is measured using exterior dimensions. Note that the conditioned space can be directly or indirectly conditioned space, and it can adjoin either ambient air or enclosed, unconditioned space. Also note that, unlike the residential *Standards,* slabs-on-grade are not considered exterior floors because they do not separate conditioned space from ambient air or unconditioned space (see discussion of **Exterior Partition** below). A floor over a ventilated crawl space or a parking garage would be an exterior floor. Likewise, in a conditioned attic space, the soffit of an overhanging eave would be considered an exterior floor/soffit because it has unconditioned space below (see Figure 3-1).

Exterior Partition *is an opaque, translucent, or transparent solid barrier that separates conditioned space from ambient air or space that is not enclosed. It separates conditioned space (including* **Indirectly Conditioned Space**, as discussed in Section 2.1.2A) from the outdoors or from spaces that are not enclosed. The terms *partition* and *barrier* are used as generic descriptors of any envelope element, including windows, soffits, skylights, metal doors, walls, roofs, etc.

Exterior Roof/Ceiling *is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below, and that is not an exterior door or skylight.* This means that the space above the roof or ceiling can be either ambient air or enclosed, unconditioned space. In either case, the envelope requirements for roofs/ceilings apply. An example of an enclosed, unconditioned space would be a ventilated attic or mechanical room. Another would be the ceiling of a conditioned office built within a taller, unconditioned warehouse space (see Figure 3-2).

Exterior Wall *is any wall or element of a wall, or any member or group of members, which defines the exterior boundaries or courts of a building and which has a slope of 60 degrees or greater with the horizontal plane. An exterior wall or partition is not an exterior floor/soffit, exterior door, exterior roof/ceiling, window, skylight, or demising wall.* This leaves only the opaque wall surfaces defined as exterior walls. They separate directly or indirectly conditioned space from the outdoors. Note that they do not include demising walls, which adjoin enclosed unconditioned space.

Exterior Wall Area *is the area of the opaque exterior surface of exterior walls.* It is measured using exterior dimensions. This area does not include windows or doors.

Fenestration or Glazing Product (same definition) *is any transparent or translucent material plus any sash, frame, mullions and dividers, in the envelope of a building, including, but not limited to: windows, sliding glass doors, french doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one-half of the door area.*

Figure 3-1: Requirements for Floor/Soffit Surfaces

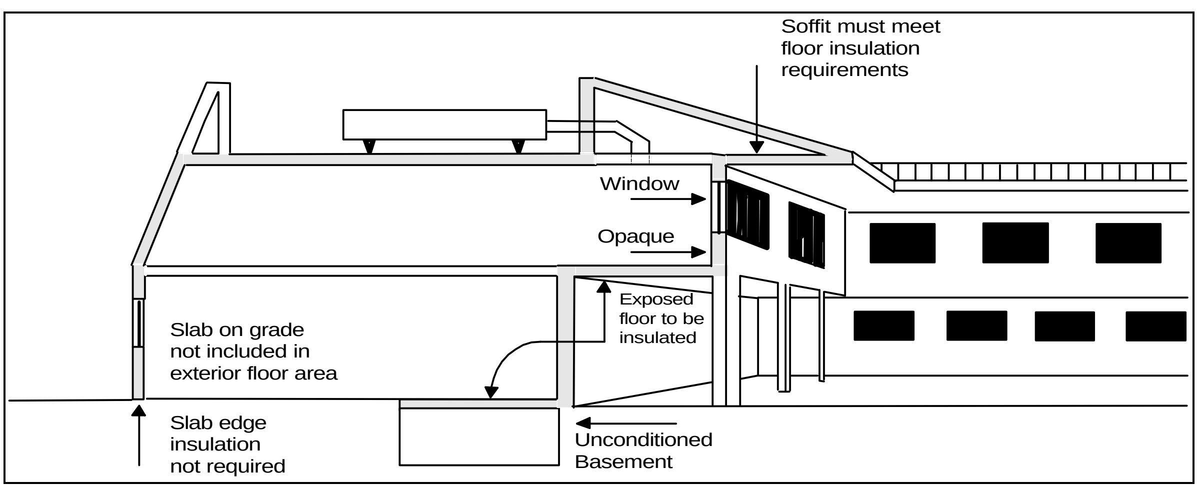
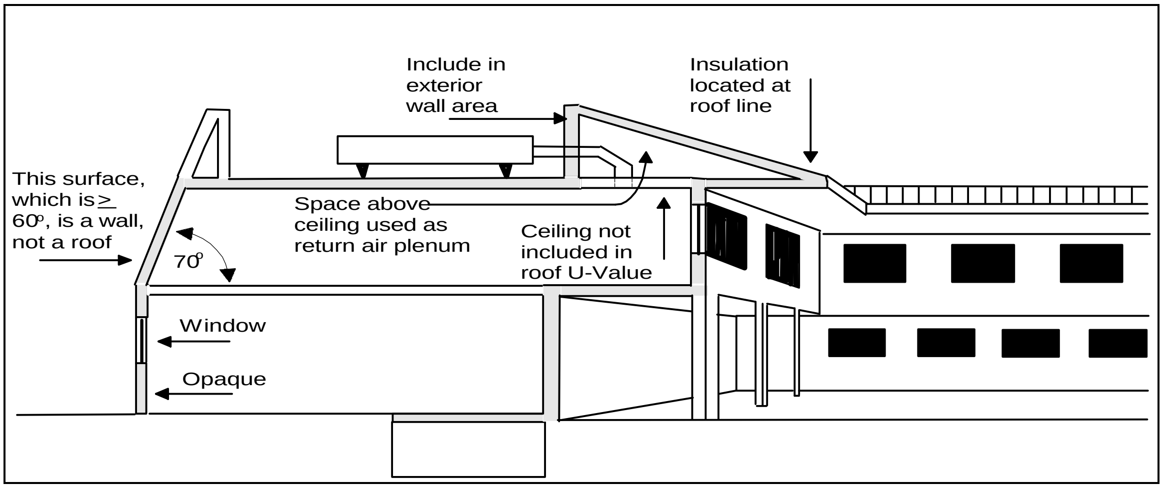


Figure 3-2: Requirements for Roof/Ceiling Surfaces



Field-Fabricated Fenestration Product or Exterior Door *is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door.* This type of product does not need to be labeled. *Field fabricated does not include site assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits and curtainwalls).* The U-value and solar heat gain coefficient are determined from the default table (see Tables 3-10 and 3-11).

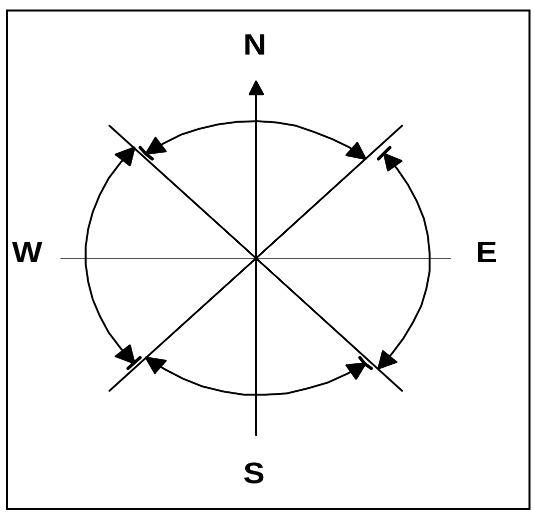
Floor/Soffit Type *is a floor/soffit assembly having a specific heat capacity, framing type, and U-value.*

Gross Exterior Roof Area *is the sum of the skylight area and the exterior roof/ceiling area.* Note that this does not include exterior door areas, such as roof hatches. Roof areas are measured using outside dimensions.

Gross Exterior Wall Area *is the sum of the window area, door area, and exterior wall area.* This area is only used to calculate limits on exterior window area.

Orientation (North, East, South and West) *see Glossary (Appendix G) definitions of* ***North-facing, East-facing, etc.*** The *Standards* make this distinction because solar heat gain differs by orientation, causing the energy flows at the envelope to vary with orientation. In general, any orientation within 45° of true north, east, south or west will be assigned to that orientation. The orientation can be determined from an accurate site plan. Figure 3-3 indicates how surface orientations are determined and what to do if the surface is oriented exactly at 45° of a cardinal orientation. For example, an *east-facing* surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

Figure 3-3: Surface Orientations

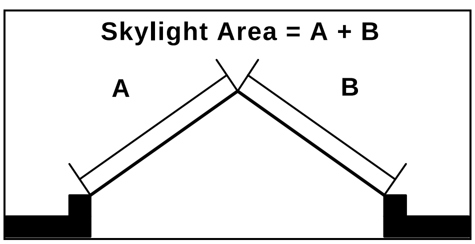


Relative Solar Heat Gain is the ratio of solar heat gain through a fenestration product (corrected for external shading) to the incident solar radiation. solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted or convected into the space.

Skylight *is glazing having a slope less than 60 degrees from the horizontal with conditioned space below, except for the purposes of complying with Standards* Section 151(f) in residential buildings. See discussion of **Slope** below.

Skylight Area *is the area of the surface of a skylight, plus the area of the frame, sash, and mullions.* Since skylights are often not planar, skylight area measurement varies from that for windows. If the skylight is a pyramid, barrel vault or other three-dimensional shape, its surface area is measured across the actual surfaces, not across the flat plane of the opening (see Figure 3-4). The only exception to this is when calculating the skylight-to-roof ratio to determine daylit area under skylights; in that case, the skylight area is the rough opening dimension (see Section 5.2.1C).

Figure 3-4: Skylight Area

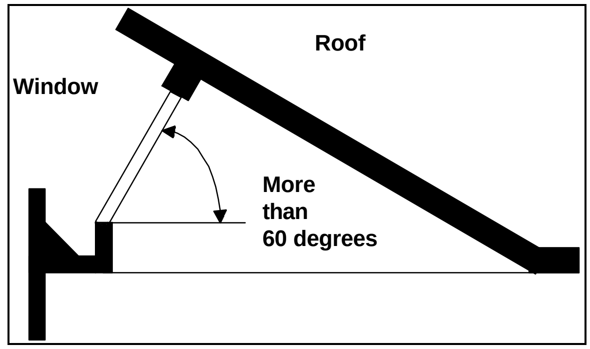


Skylight Type is a skylight assembly having a specific solar heat gain coefficient, whether translucent or transparent, and U-value.

Slope is used to distinguish between walls and roofs (see **Exterior Roof/Ceiling** definition above). If an exterior partition has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall (see Figure 3-5). This definition extends to fenestration products, including the windows in walls and any skylights in roofs.

Solar Heat Gain Coefficient (SHGC) is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

Figure 3-5: Slope of a Wall or Window (Roof or Skylight slope is less than 60°)



Solar Heat Gain Coefficient (SHGC) is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

Wall Type is a wall assembly having a specific heat capacity, framing type, and U-value.

Well Index (see Section 5.2.1C)

Window *is glazing that is not a skylight.* Note that the window includes any sash, framing, mullions or dividers.

Window Area *is the area of the surface of a window, plus the area of the frame, sash, and mullions.* As a practical matter, window area is generally taken from the rough opening dimensions. To the extent this opening is slightly larger than the frame, the rough opening area will be a bit larger than the formally defined window area. Use the rough opening area, except for a window in a door. In this case, use the area of the frame that holds the glazing material. For unframed glass doors, use the rough opening of the entire door. If the window is not planar, as with a protruding garden window, then the entire surface area of the fenestration product is used (see **Skylight Area**).

Window Type is a window assembly having a specific solar heat gain coefficient, relative solar heat gain, and U-value.

Window Wall Ratio *is the ratio of the window area to the gross exterior wall area.* Calculate the window area from the rough opening dimensions and divide by the gross exterior wall area, which does not include demising walls. Glazing area in demising walls has no limit and any glazing in demising walls is not counted as part of the exterior wall/window ratio.

B. Insulation R-value (§143(a))

Thermal Resistance (R) *is the resistance of a material or building component to the passage of heat in (hr x ft^2 x °F)/Btu.*

The R-value of an insulation material is a measure of its thermal resistance. The higher the R-value, the greater the thermal resistance or the better the insulating value of the material. The thicker the material, the greater its R-value. R-values are used in the Envelope Component Method as minimum efficiency requirements. They are also used as part of the calculation of the U-values of opaque building envelope assemblies. See the following Sections (C through F) on U-values for more information on these calculations.

Most types of insulating material used in California must be certified by its manufacturer as meeting the California Quality Standards for Insulating Material. See Section 118 for a more complete description of these requirements.

C. Overall Assembly U-value (§143(b))

U-value *is the overall coefficient of thermal transmittance of a construction assembly in Btu/(hr x ft^2 x °F), including air film resistance at both surfaces.*

The U-value describes the rate of heat flow through a building surface. The *Standards* specify U-value limits which translate into minimum insulation requirements for the envelope (see Tables 3-20 and 3-21). The U-value tells how many Btu (British thermal units) of heat energy will pass through one square foot of surface area in an hour, for every degree of difference, between inside and outside air temperature. The higher the temperature difference, the more heat will flow. It follows, then, that lower U-values mean smaller quantities of heat flow, less winter heat loss and less summer heat gain. U-values are always calculated to three significant digits.

The U-value calculation varies depending on the composition of the wall, roof, or other assembly under consideration. The variations are discussed in the following sections.

In addition to the insulating properties of the materials that make up a construction assembly, such as a wall, thin layers of still air cling to the surface of the assembly. These air films, as they are called, add to the insulating value of the assembly. They are accounted for in the U-value, and can have a significant effect on envelope compliance, especially for uninsulated assemblies.

In U-value calculations, there are standard air film R-values that are used for compliance purposes (see the following subsections for discussion of U-value calculations). The standard values assume that the interior air film is in still air, and that the exterior air film is in a 15 mile per hour breeze, which considerably reduces its insulating value. Table 3-1 lists the standard air film R-values.

The following subsections describe how the U-values of various envelope components are calculated. These U-values are used to demonstrate compliance with the envelope *Standards*.

> NOTE:
>
> Weight averaging of assemblies requires a U-value. R-values cannot be weight averaged.

D. Wood Frame U-values (§141(c)4.B)

Framed Partition or Assembly *is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.*

Wood-framed assemblies are common in smaller nonresidential buildings, and are known by such names as stud walls, roof rafters and floor joists.

They use small dimension lumber as the structural elements, typically spaced on 16 inch or 24 inch centers. The cavities between the framing members typically are filled with insulation.

Table 3-1: Standard Air Film R-values

AIR FILMS [1]				
	Wall	**Roof**		**Floor**
		Flat [2]	45° Angle	
Inside	0.68	0.61	0.62	0.92
Outside	0.17	0.17	0.17	0.17
AIR SPACES [4]				
0.5 inch	0.77	0.73	0.86	0.77
0.75 inch	0.84	0.75	0.81	0.85
1.5 inch	0.87	0.77	0.80	0.94
3.5 inch [5]	0.85	0.80	0.82	1.00

NOTE: Values from ASHRAE Handbook of Fundamentals, 1993 edition, Chapter 22, Tables 1 & 2.

[1] Assumes a non-reflective surface emittance of 0.90 and winter heat flow direction.
[2] Use the "Flat" roof R-values for roof angles between horizontal and 22 degrees.
[3] Use the 45 degree roof R-values for roof angles between 23 and 60 degrees.
[4] Assumes mean temperature of 90 degrees Fahrenheit, temperature difference of 10 degrees Fahrenheit, surface emittance of 0.82 and winter heat flow direction.
[5] Use these R-values for air spaces greater than or equal to 3-2 inches, such as attics.

Any time a typical wood-frame assembly is used, the U-values listed in Table B-2 (see Appendix B) can be used (a portion of Table B-2 is included as Table 3-2). Table B-2 provides a wide range of typical wood-framed assemblies.

To use Table B-2, identify the appropriate type and spacing of the framing. Next, locate the R-value of the cavity insulation. Finally, use the R-value of the layer of insulated sheathing (such as rigid foam insulation board) attached to the assembly and select the row of the table showing the U-value of the assembly. Use the "zero" R-value if there is no insulated sheathing. Note that *insulated sheathing* does not include ordinary building materials such as plywood or stucco; it is rigid board material designed to be used as insulation. Examples of this type of insulation are polystyrene and polyisocyanurate. These default U-values must be used for compliance purposes, unless calculations are submitted for each assembly.

Likewise, if the assembly is not included in the table, or if the assembly is a framed floor, ceiling, or soffit, the U-value must be calculated using the parallel path method, in which case the applicant must submit calculations using ENV-3 (see Section 3.3.6).

Table 3-2: Wood Framed Assembly U-values (excerpt from Table B-2, Appendix B)

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value
2x4 @ 16" O.C.	11 (compressed)	0	0.098
		4	0.068
		5	0.064
		7	0.056
		8.7	0.051
	13	0	0.088
		4	0.063
		5	0.059
		7	0.052
		8.7	0.048
	15	0	0.081

Parallel Path Method. Wood framed assembly U-values are calculated using the parallel path method (see ENV-3 Wood Framed Assembly). This method takes account of the fact that heat flows at a different rate through the solid wood framing portion of the surface than through the insulated cavity portion. The U-value developed by the method is essentially an area-weighted average of the U-values of the frame and cavity areas. The parallel path method is described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22 (see Appendix B). For compliance purposes, the parallel path method calculation is done for each wood-framed assembly using the ENV-3 form. Refer to Section 3.3.6 for a step-by-step explanation of this calculation and the form.

Because the parallel path method weights the U-values of the framing and the cavity areas, a key number in the calculation is the *framing percent* *age.* This number describes the percentage of the surface area that is occupied by framing; the rest is occupied by cavity and insulation. In order to simplify the calculation and to avoid confusion, the Energy Commission has adopted common framing percentages, found below in Table 3-3.

Table 3-3: Wood Framing Percentage

Assembly Type	Framing Spacing	Framing Percentage
Walls	16" o.c. 24" o.c.	15% 12%
Floors	16" o.c. 24" o.c.	10% 7%
Roofs	16" o.c. 24" o.c.	10% 7%
1993 ASHRAE Handbook of Fundamentals, Chapter 22		

E. Metal Frame U-values (§141(c)4.C)

Framed Partition or Assembly *is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.* Metal framing, typically using steel studs, rafters or joists made of rolled shapes of light gauge steel, is common in non-combustible construction. The framing techniques are similar to those for wood framing; small dimension structural members are typically placed on 16 inch or 24 inch centers, and the cavities between the framing members are filled with insulation. This method does not apply when the framing spacing is 32 inches or more.

Metal-framed assemblies have greater heat transfer than wood-framed assemblies, of similar construction. This is because the steel material is an effective heat conductor. Heat flows rapidly through the framing members, bypassing the cavity insulation. The net result is substantial reduction in the effectiveness of the insulation.

To account for this effect, the zone method is used for determining the U-value of a metal-framed assembly instead of the parallel path method. This method is described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22 (see Appendix B). A hand calculation using the zone method is elaborate, and is not recommended for use without training.

Other alternatives to performing zone method calculations include the use of ENV-3 for Metal Framed Assemblies, default table (Table 3-4), and a computer program were developed by the Energy Commission to determine the U-values of construction assemblies, including those with metal framing (see Appendix B).

Table 3-4 is an excerpt from Table B-2, the Wall Assembly U-value Table found in Appendix B, which provides U-values for a wide range of typical metal-framed wall assemblies. They were calculated using the zone method. These values may be used for compliance purposes, unless the applicant submits calculations for each assembly separately (using form ENV-3 Metal Frame; see Section 3.3.4). Interpolating or extrapolating values in this table is prohibited.

To use this table, identify the appropriate type and spacing of the framing. Next, locate the R-value of the cavity insulation. Finally, use the R-value of the layer of insulated sheathing attached to the assembly and select the row of the table showing the U-value of the assembly. Use "zero" R-value if there is no insulated sheathing.

Table 3-4: Metal Framed Assembly U-values (excerpt from Table B-2)

Framing Type and Spacing	Framed Wall Assembly U-Values		
	Framing Cavity R-Value	Insulated Sheathing R-Value	Metal Wall U-Value
2x4 @ 16" o.c.	R-11	0.0	0.202
		4.0	0.112
		5.0	0.101
		7.0	0.084
		8.7	0.073

Note that *insulated sheathing* does not include ordinary building materials such as plywood or stucco; it is rigid board material designed to be used as insulation. Examples of this type of insulation are polystyrene and polyisocyanurate.

If the value in Table B-2 is not used, or if the assembly is a metal-framed floor, ceiling or soffit, the U-value may be calculated using the metal framing factors found in Table 3-5 (see Appendix B, Table B-3). Using the ENV-3 Metal Framed

Assembly form described more fully in Section 3.3.4, multiply the values in this table by the sum of R-values of all layers including air films, excluding any insulated sheathing. Add the insulated sheathing R-value, if any, to obtain the total assembly R-value. Using this value, calculate the U-value.

Table 3-5: Metal Framing Factors

METAL FRAMING FACTORS*			
Stud Spacing	**Stud Depth**	**Insulation R-Value**	**Framing Factor**
16" o.c.	4"	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6"	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24" o.c.	4"	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6"	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308
R-value calculation for Exterior Wall Assemblies with Metal Studs, July 19, 1990, Staff Draft Docket 90-CON-1.			
*Correction to metal framing factors applies to the entire assembly including: interior air films, interior surfaces, cavity/insulation, exterior surfaces, and exterior air films.			

F. *Masonry U-values (§141(c)4.E)*

Masonry wall assemblies are typically built using concrete masonry units (block), or with various clay products (brick or tile). They also include solid masonry or concrete assemblies, such as tilt-up concrete walls. The heat flow across these walls can be complex because of the voids in the wall, the solid material bridges through the wall, and the reinforcing and grouting of some of the voids for structural reasons.

The recommended procedure for determining masonry wall U-values is to use the tables of values provided in this *Manual* in Tables B-4 through B-6 (see Appendix B). Alternatively, it is permissible to use either the method of transverse isothermal planes described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22, or the method described in *Energy Calculations and Data*, published by the Concrete Masonry Association of California and Nevada, 1986.

A simplified version of the latter method was used to develop Table B-4, excerpted in Table 3-6. This table lists various typical hollow unit masonry units by nominal wall thickness (12", 10", etc.), and by material type. For example, NW CMU refers to normal weight concrete masonry units (concrete blocks). The table also provides for the three typical core treatments: solid grout and two types of partially grouted core treatments. The ungrouted cells in partially grouted walls are either empty or filled with perlite insulation. The table gives the U-value for the wall, including interior and exterior air films. It also provides the total R-value and the heat capacity (HC) (see Subsection 3.1.2G for more on heat capacity). The use of these numbers in determining the U-value of complex masonry assemblies is explained in Section 3.3.5 (ENV-3: Proposed Masonry Wall Assembly).

Table 3-6: Properties of Hollow Unit Masonry Walls (excerpt from Table B-4)

Type			Core Treatment		
			Solid Grout	Partly Grouted with Ungrouted Cells	
				Empty	Filled w/Perlite
12"	LW CMU	U	0.51	0.43	0.30
		Rt	2.0	2.3	3.3
		HC	23.0	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		Rt	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rt	1.8	2.0	2.8
		HC	24.8	16.5	16.5

Table B-5 is used to find the values for solid masonry assemblies not made up of hollow masonry units (e.g. poured concrete), and is excerpted in Table 3-7.

Table 3-7: Properties of Solid Unit Masonry and Solid Concrete Walls (excerpt from Table B-5)

Type		Layer Thickness, inches 3	4	5	6
LW CMU	U	na	0.71	0.64	na
	Rw	na	1.4	1.6	na
	HC	na	7.00	8.75	na
MW CMU	U	na	0.76	0.70	na
	Rw	na	1.3	1.4	na
	HC	na	7.67	9.58	na
NW CMU	U	0.89	0.82	0.76	na
	Rw	1.1	1.2	1.3	na
	HC	6.25	8.33	10.42	na
Clay Brick	U	0.80	0.72	0.66	na
	Rw	1.3	1.4	1.5	na
	HC	6.30	8.40	10.43	na
Concrete	U	0.96	0.91	0.86	0.82
	Rw	1.0	1.1	1.2	1.2
	HC	7.20	9.60	12.00	14.40

G. Heat Capacity (Tables 3-8 and 3-9)

Heat Capacity (HC) *of an assembly is the amount of heat necessary to raise the temperature of all the components of a unit area in the assembly one degree F. It is calculated as the sum of the average thickness times the density times the specific heat for each component, and is expressed in Btu per square foot per degree F.*

Heat capacity describes the thermal mass of an assembly. It is used in the prescriptive envelope requirements for walls and floors, where the U-value criterion is tied to the heat capacity of the assembly.

Table 3-8: Effective R-Values for Interior Insulation Layers on Structural Mass Walls (excerpt from Table B-6)

Type Actual Thick	Frame	Furring space R-value without framing effects 0	1	2	3	4	5	6	7	8	9	10
Any	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10
0.5"	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	na	na
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	na	na
0.75"	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	na	na
1.0"	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	na	na

For a single layer, homogeneous wall or floor, such as poured concrete walls with no applied finish materials, heat capacity can be calculated by multiplying the weight of the wall (pounds per square foot) times the specific heat. For instance, a 6 inch concrete wall (specific heat = 0.20 Btu/lb-°F) with a weight of 70 pounds per square foot would have an HC of 70 x 0.20 or 14 Btu/ft^2-°F. To calculate the wall weight from the density (pounds per cubic foot), multiply the density by the wall thickness (inches) and then divide by 12 (inches) which gives the wall weight in pounds per square foot.

For assemblies made up of many layers, the HC may be calculated separately for each layer and summed. The Proposed Construction Assembly, form ENV-3, includes a procedure for calculating HC in simple layered assemblies (see Section 3.3.6).

Table 3-9 lists the thermal properties of typical, thermally massive construction materials. See Appendix B, Table B-1, for a more thorough listing of the thermal characteristics of materials.

The HC of unit masonry walls, such as those made of concrete block or brick, are too complicated to calculate by this method. Appendix B, Materials Reference includes Tables B-4 and B-5 with HCs calculated for a large variety of masonry wall assemblies. See Section 3.1.2F for an introduction to these tables.

Table 3-9: Thermal Mass Properties

Matter	Conductivity (Btu/hr-ft-oF)	Density (Lbs/cf)	Specific Heat (Btu/lb-oF
Adobe	0.33	120	0.20
Heavy Concrete	0.98	140	0.20
Lightweight Concrete	0.36	85	0.20
Gypsum	0.09	50	0.26
Masonry Veneer	0.62	127	0.20
Masonry Infill	0.44	120	0.20
Concrete Masonry Unit	0.59	105	0.20
Grouted Concrete Masonry Unit	1.00	134	0.20
Stucco	0.47	105	0.20
Tile in Motar	0.67	120	0.20
Solid Wood (fir)	0.07	32	0.33
ASHRAE Handbook of Fundamentals, Table 4, Chapter 22			

H. Fenestration U-values (§141(c)4.D)

The U-value for a fenestration product describes the rate of heat flow through the entire unit, not just the glass or plastic glazing material. The U-value includes the heat flow effects of the glass, the frame, and the edge-of-glass conditions (there may be spacers, sealants and other elements that affect heat conduction).

The Glossary lists many of the new terms and product characteristics to acquaint readers with some of the possibilities.

Manufactured Windows and Skylights. Because of inconsistencies in the methods used by window manufacturers in developing and reporting U-values for their fenestration products, a joint industry/ government effort has been underway to standardize procedures.

Standards Section 116(a)2 requires every installed manufactured window or skylight to display a label indicating its rated U-value and SHGC solar heat gain coefficient.

The manufacturers can obtain U-value and SHGC ratings from the National Fenestration Rating Council's (NFRC) rating procedure, or from the Energy Commission's Default Tables (Tables 3-10 and 3-11).

The NFRC has available a *Certified Products Directory* containing NFRC certified U-values for more than 3800 products. The directory is available by contacting:

NFRC
1300 Spring Street, 5th Floor
Silver Springs, MD 20910
(301) 589-6372

Table 3-10: Default Fenestration Product U-Values

Frame Type[1]	Product Type	Single Pane U-value	Double Pane U-value[2]
Metal	Operable	1.28	0.87
Metal	Fixed	1.19	0.72
Metal	Greenhouse/ Garden Window	2.26	1.40
Metal	Doors	1.25	0.85
Metal	Skylight	1.72	0.94
Metal, Thermal Break	Operable		0.71
Metal, Thermal Break	Fixed		0.60
Metal, Thermal Break	Greenhouse/ Garden window		1.12
Metal, Thermal Break	Doors		0.64
Metal, Thermal Break	Skylight		0.80
Non-Metal	Operable	0.99	0.60
Non-Metal	Fixed	1.04	0.57
Non-Metal	Doors	0.99	0.55
Non-Metal	Greenhouse/ Garden window	1.94	1.06
Non-Metal	Skylight	1.47	0.68

[1] Metal includes any field-fabricated product with metal cladding. Non-metal framed manufactured fenestration products with metal cladding must add 0.04 to the listed U-value. Non-Metal frame types can include metal fasteners, hardware, and door thresholds. Thermal break product design characteristics are:

a. The material used as the thermal break must have a thermal conductivity ≤ 3.6 Btu-inch/hr-ft^2-°F,
b. The thermal break must produce a gap of ≥ 0.210",
c. All metal members of the fenestration product exposed to interior and exterior air must incorporate a thermal break meeting the criteria in (a) and (b) above.

In addition, the fenestration product must be clearly labeled by the manufacturer that it qualifies as a thermally broken product in accord with Section 116.

[2] For all dual glazed fenestration products, adjust the listed U-values as follows:

a. Subtract 0.05 for spacers of 7/16" or wider.
b. Subtract 0.05 for products certified by the manufacturer as low-E glazing.
c. Add 0.05 for products with dividers between panes if spacer is less than 7/16" wide.
d. Add 0.05 to any product with true divided lite (dividers through the panes).

I. Solar Heat Gain Coefficient (§141(c)5)

The SHGC is a measure of the quantity of solar heat entering a window or skylight; the lower the SHGC, the lower the amount of solar heat. A low SHGC reduces solar heat gains, thereby reducing the amount of air conditioning energy needed to maintain comfort levels in the building.

SHGC are reported on the product label by glazing material manufacturers for their products. In cases where the specific glazing product is not known, values from the default Solar Heat Gain Coefficient Table 3-11 are used.

Table 3-11: Default Solar Heat Gain Coefficient

Frame Type	Product	Glazing	Total Window SHGC Single Pane	Total Window SHGC Double Pane
Metal	Operable	Uncoated	0.80	0.70
Metal	Fixed	Uncoated	0.83	0.73
Metal	Operable	Tinted	0.67	0.59
Metal	Fixed	Tinted	0.68	0.60
Metal, Thermal Break	Operable	Uncoated	0.72	0.63
Metal, Thermal Break	Fixed	Uncoated	0.78	0.69
Metal, Thermal Break	Operable	Tinted	0.60	0.53
Metal, Thermal Break	Fixed	Tinted	0.65	0.57
Non- Metal	Operable	Uncoated	0.74	0.65
Non- Metal	Fixed	Uncoated	0.76	0.67
Non- Metal	Operable	Tinted	0.60	0.53
Non- Metal	Fixed	Tinted	0.63	0.55

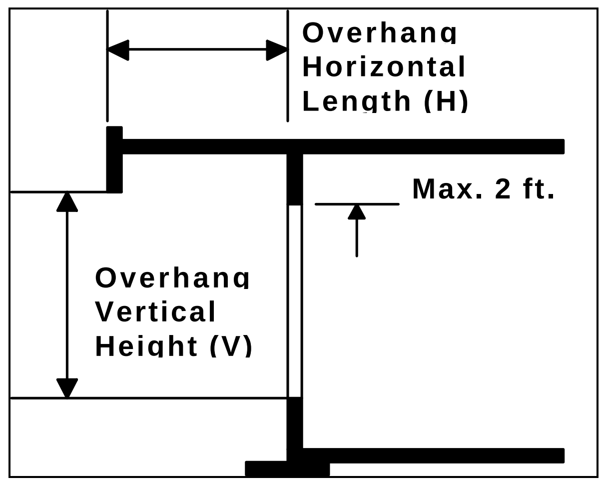
SHGC = Solar Heat Gain Coefficient

Note that, unlike the residential performance compliance procedures, nonresidential windows are not allowed credit for any interior shading such as *draperies* or blinds. Only exterior shading devices permanently attached to the building, or a structural component of the building, can be modeled (i.e. shade screen). Manually operable shading devices cannot be modeled. Overhangs can be credited using the Relative Solar Heat Gain procedure (see 3.1.2J below).

J. Relative Solar Heat Gain §143(a)5.C)

This value is essentially the same as SHGC, except for the external shading correction. It is calculated by multiplying the SHGC of the fenestration product by the overhang factor.

Figure 3-6: Overhand Dimensions



Overhang factor may either be calculated automatically (see Equation 3-1) or may be taken from Table 3-12. The factor depends upon the ratio of the overhang horizontal length (H), and the overhang vertical height (V). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing, as shown in Figure 3-6. An overhang factor may be used *if the overhang extends beyond both sides of the window jamb a distance equal to the overhang projection (Section 143(a)5.C.ii).* The overhang projection is equal to the overhang length (H) as shown in Fig. 3-6. If the overhang is continuous along the side of a building, this restriction will usually be met. If there are overhangs for individual windows, each must be shown to extend far enough to each side of the window.

Equation 3-1: Relative Solar Heat Gain

RSHG = SHGCwin x [1 + aH/V + b(H/V)^2*]*

Where

RSHG = Relative solar heat gain.

$SHGC_{win}$ = Solar heat gain coefficient of the window.

H = Horizontal projection of the overhang from the surface of the window in feet, but no greater than V.

V = Vertical distance from the window sill to the bottom of the overhang, in feet.

a = -0.41 for North-facing windows, -1.22 for South-facing windows, and -0.92 for East- and West-facing windows.

b = 0.20 for North-facing windows, 0.66 for South-facing windows, and 0.35 for East- and West-facing windows.

Table 3-12: Overhang Factors

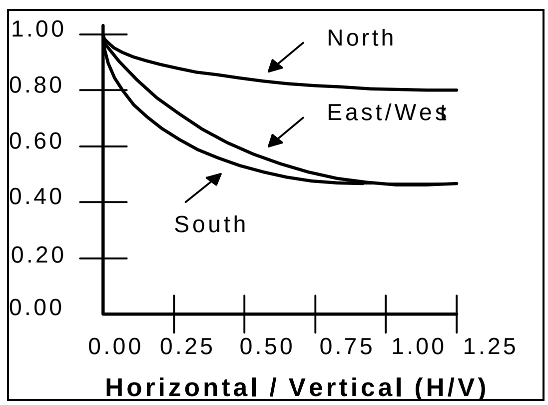
H/V	North	East/West	South
0.00	1.00	1.00	1.00
0.05	0.98	0.95	0.94
0.10	0.96	0.91	0.88
0.15	094	0.87	0.83
0.20	0.93	0.83	0.78
0.25	0.91	0.79	0.74
0.30	0.90	0.76	0.69
0.35	0.88	0.72	0.65
0.40	0.87	0.69	0.62
0.45	0.86	0.66	0.58
0.50	0.85	0.63	0.56
0.55	0.84	0.60	0.53
0.60	0.83	0.57	0.51
0.65	0.82	0.55	0.49
0.70	0.81	0.53	0.47
0.75	0.80	0.51	0.46
0.80	0.80	0.49	0.45
0.85	0.79	0.47	0.44
0.90	0.79	0.46	0.44
0.95	0.79	0.44	0.44
1.00	0.79	0.43	0.44
1.05	0.79	0.43	0.44
1.10	0.79	0.43	0.44
1.15	0.79	0.43	0.44
1.20	0.79	0.43	0.44
1.25	0.79	0.43	0.44

In addition, if the bottom of the overhang (shading cut-off edge) is more than two vertical feet higher than the top of the window (window head), then the overhang does not qualify to receive an overhang factor.

To use Table 3-12, measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cut-off point of the overhang (V). Then calculate H/V. Enter the Table at that point. Move across to the column that corresponds to the orientation of the window and find the overhang factor. Note that any value of H/V greater than one has the same overhang factor (for a given orientation).

Figure 3-7 graphs the overhang factors of the various orientation as a function of H/V. It shows that overhangs have only a minor effect on the north (maximum reduction in SHGC is only about 20 percent). East, west and south overhangs can achieve reductions of 55 - 60 percent. The benefits of the overhang level off as the overhang becomes large. (Note: this graph is presented only to illustrate the benefits of overhangs. Do not use the graph to scale values of the overhang factor; use Table 3-12 or calculate the value directly from Equation 3-1.)

Figure 3-7: Graph of Overhang Factors



Example 3-1: RSHG Calculation

Question
An east-facing window has glass with a solar heat gain coefficient of 0.71. It has a fixed overhanging eave that extends three feet out from the plane of the glass (H=3), and which is six feet above the bottom of the glass (V=6). NOTE: the overhang extends more than three feet beyond each side of the glass and the top of the window is less than two feet vertically below the overhang. What is the RSHG for this window?
Answer
First, calculate H/V. This value is 3 / 6 = 0.50. Next, find the overhang factor from Table 3-12. For east-facing windows, this value is 0.63. Finally, multiply it by the solar heat gain coefficient to obtain the RSHG: 0.63 x 0.71 = 0.45 = RSHG.

3.2 ENVELOPE DESIGN PROCEDURES

3.2.1 Mandatory Measures

The mandatory measure requirements apply to new construction, additions and altered envelope components.

A. Doors, Windows and Skylights (§116)

The mandatory measures for doors, windows and skylights affect the air-tightness of the units and how their U-value and SHGC are determined. Fenestration products must be labeled with a U-value and SHGC and the manufacturer or independent certifying organization must certify that the product meets the air infiltration requirements of Section 116(a). Doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-13.

For field-fabricated products or an exterior door, the *Standards* require that the unit be caulked, gasketed, weather-stripping or otherwise sealed (Section 116(b)). Unframed glass doors and fire doors are the two exceptions to these requirements.

Where possible, it is best to decide what make and model of fenestration will be used before completing compliance documents. See Section 3.1.2H for information on obtaining the NFRC *Certified Products Directory.*

Table 3-13: Maximum Air Infiltration Rates

	Windows (CFM/sf) of window area	**Residential Doors** (CFM/sf) of door area	**All Other Doors** (CFM/sf) of door area	
Type	All	Swinging, Sliding	Sliding, Swingingg (single door)	Swinging (double door)
Rate	0.3	0.3	0.3	1.0

If the specifier does not know the make and model number of the fenestration products to be installed, there are four options:

- **Look up the U-values and SHGC for a number of similar products in a fenestration directory and use the highest value.** This will help to ensure that whatever product is installed, the U-value and SHGC will not be higher. A building inspection failure will result when a product that is less efficient than specified on the plans is installed.
- **Use the appropriate U-value and SHGC from the Default Fenestration Product table (see Tables 3-10and 3-11).**
- **Use the U-value and SHGC from the Envelope Prescriptive requirements** (Tables 3-20 and 3-21) The plans should also include a note to the buyer that the U-value and SHGC of the product purchased and installed must match or be lower than specified in the compliance documentation.
- **Specify a particular product and state "or equivalent."** Again, the plans should include a note to the buyer that the U-value and SHGC of the product purchased and installed must

match or be lower than specified in the compliance documentation.

B. Joints and Openings (§117)

The basic requirement of this section is that all joints and other openings in the building envelope that are potential sources of air leakage be caulked, gasketed, weather-stripped, or otherwise sealed to limit air leakage into or out of the building. This applies to penetrations for pipes and conduits, ducts, vents and other openings. It means that all gaps between wall panels, around doors Ceiling joints, lighting fixtures, plumbing openings, doors and windows, and other construction joints must be well sealed.

Ceiling joints, lighting fixtures, plumbing openings, doors and windows should all be considered as potential sources of unnecessary energy loss due to infiltration. No special construction requirements are necessary for suspended (T-bar) ceilings. Standard construction (insulation on ceiling tiles) is adequate for meeting the infiltration/exfiltration requirements.

C. Insulation Materials (§118)

The California Quality Standards for Insulating Materials, which became effective on January 1, 1982, ensure that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.
Manufacturers must certify insulating materials to comply with California Quality Standards for Insulating Materials. Builders may not install the types of insulating materials listed in Table 3-14 unless the product has been certified by the manufacturer. Builders and enforcement agencies should use the Department of Consumer Affairs *Consumer Guide and Directory of Certified Insulation Material* to check compliance. (Note this is not an Energy Commission publication.) If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Thermal Insulation Program at
(916) 574-2046.

The California Quality Standards for Insulating Materials also require that all exposed installations of faced mineral fiber and mineral aggregate insulations must use fire retardant facings that have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications.

Flame spread ratings and smoke density ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

D. Demising Walls (§118(e))

Demising walls separating conditioned space from enclosed unconditioned space, must be insulated with a minimum of R-11 insulation if the wall is a framed assembly. This requirement applies to buildings meeting compliance under the prescriptive or performance approach. This requirement assures at least some insulation in a wall where an adjoining space may remain unconditioned indefinitely.

Table 3-14: Certified Insulating Materials

Type	Form
Aluminum foil	reflective foil
Cellular glass	board form
Cellulose fiber	loose fill and spray applied
Mineral aggregate	board form
Mineral fiber	blankets, board form, loose fill
Perlite	loose fill
Phenolic	board form
Polystyrene	board form, molded extruded
Polyurethane	board form and field applied
Polyisocyanurate	board form and field applied
Urea formaldehyde	foam field applied
Vermiculite	loose fill

3.2.2 Prescriptive Envelope Component Approach (§143(a))

The Envelope Component Approach is the simplified approach. Under this approach, each of the envelope assemblies (walls, roofs, floors, windows, skylights) complies individually with its requirement. If one piece of the envelope does not comply, the entire envelope does not comply. The simplicity of this approach means there can be no trade-offs between components. If one or more of the envelope components cannot meet its requirement, the alternative is to use either the Overall Envelope or the Performance Approach, either of which allows trade-offs between components.

Under the Envelope Component Approach, the requirement for each opaque (non-glazing) component takes one of two forms: R-value of its insulation or overall U-value of the assembly. Glazing component requirements address U-value, solar heat gain coefficient, and an upper limit on glazing area. The requirements are found in Tables 3-20 and 3-21 with applicable excerpts in the following sections. The requirements vary by climate zone, occupancy and, in some cases, heat capacity. Compliance is demonstrated on the ENV-2, Envelope Component Method form.

A. Exterior Roofs and Ceilings (§143(a)1)

Exterior roofs or ceilings can meet the component requirements in one of two ways: install the required R-value of insulation, or demonstrate that the overall U-value of the assembly meets the required U-value (Section 141(c)4). If the insulation by itself meets the R-value requirement, then that component complies with this approach. If not, then the U-value calculation allows for the overall insulating qualities of the assembly which also acknowledges the effects of wood or metal framing. For ceilings the effects of T-bar framing and metal lighting fixtures must be included in determining the overall U-value of an assembly.

When recessed lights are not IC-rated, the weighted average ceiling assembly is calculated as two parallel assemblies:

1. The effective R-value of the ceiling assembly is the sum of (a) T-bar/acoustic tile (to account for the metal grids, assume 1/2 the tile's R-value); (b) ceiling insulation; and (c) two inside air film resistances (0.61 R-value per air film).

2. The effective R-value of the light fixtures is calculated as the sum of two inside air film resistances (0.61 R-value per air film). If the fixtures include plastic diffusers, the R-value of the light fixture should be calculated as two air film resistances and a 1.5 inch air space (0.77 R-value).

   NOTE: When fixtures are IC-rated and covered by insulation, the insulation R-value alone may be used to show compliance with the prescriptive requirements or the above calculation can be modified to include the insulation R-value in the light fixture assembly.

The two parallel assemblies are then weight averaged and the U-value calculated.

> NOTE:
>
> You cannot use the EZFRAME program for T-bar/drop ceiling assemblies.

When envelope calculations are prepared before the lighting plan, the following default values may be used to determine the percentage of the ceiling assembly made up of light fixtures:

General Commercial/Industrial:

Work Buildings	10%
Grocery	15%
Industrial/Comm.Storage	7%
Medical Buildings	12%
Office Building	12%
Religious Worship, Auditorium, and Convention Ctr	16%
Restaurants	12%
Retail and Wholesale	16%
Schools	15%
Theaters	12%
All Others	7%

Figure 3-8: Roof/Ceiling Flowchart

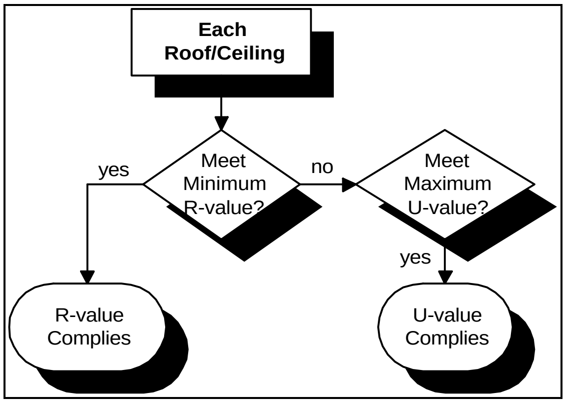


Table 3-15: Roof/Ceiling Requirements

Nonresidential: Roof/Ceiling					
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
R-value Wood or Metal	**19**	**19**	**11**	**19**	**19**
U-value	0.057	0.057	0.078	0.057	0.057
Residential High-rise: Roof/Ceiling					
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
R-value Wood or Metal	**30**	**19**	**19**	**30**	**30**
U-value	0.037	0.051	0.051	0.037	0.037

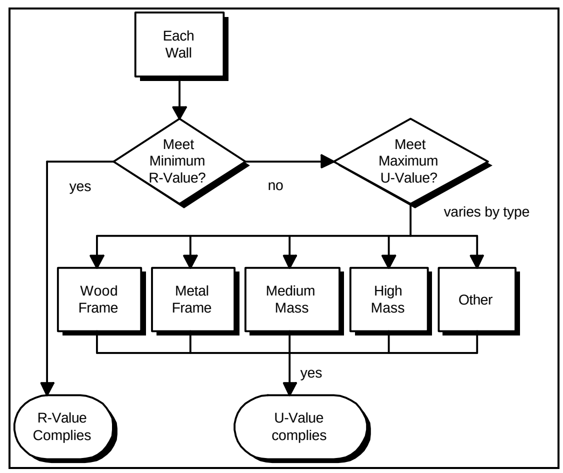
B. Exterior Walls (§143(a)2)

Exterior walls can meet the component requirements in one of two ways: install the required R-value of insulation, or demonstrate that the overall U-value of the assembly meets the required U-value (Section 141(c)4). If the insulation by itself meets the R-value requirement, then that component complies under this approach. If not, then the U-value calculation allows credit for the overall insulating qualities of the assembly which includes accounting for the effects of wood or metal framing in the assembly.

The required U-value depends on the type of wall construction. There are five classes of wall: wood frame, metal frame, medium mass, high mass and other. The "other" category is used for any wall type that does not fit into one of the other four wall classes. The mass walls are distinguished by their heat capacity (HC); the higher the HC, the higher the wall U-value may be (see Heat Capacity discussion in Section 3.1.2G). Medium mass walls have an HC between 7 Btu/ft^2-°F and 15 Btu/ft^2-°F. High mass walls have an HC greater than 15 Btu/ft^2-°F .

Framed wall assemblies will seldom have an HC greater than 7 Btu/ft^2-°F . Medium mass walls will have at least one fairly heavy layer, such as two coat stucco or a brick veneer, in order to have an HC higher than 7 Btu/ft^2-°F . High mass walls are generally of masonry or concrete construction.

Figure 3-9: Wall Flowchart



The proposed wall U-value must be calculated by an appropriate method (see Section 141(c)4). Framed assemblies must account for framing affects. Masonry assemblies must account for two dimensional heat flow. See Section 3.1.2D, E, and F for a complete discussion of the various methods and forms for determining U-values.

C. Demising Walls (§143(a)3 & 5)

Demising walls, separating conditioned space from enclosed unconditioned space, must be insulated with a minimum of R-11 insulation if the wall is a framed assembly. If it is not a framed assembly, then no insulation is required. This only applies to the opaque portion of the wall. A *demising wall* is not an *exterior wall.*

The rationale for insulating demising walls is that the space on the other side may remain unconditioned indefinitely. For example, the first tenant in a warehouse building cannot know whether the future neighbor will use the adjoining space as unheated warehouse space or as an office. This requirement assures at least some insulation in the wall.

D. Exterior Floors and Soffits (§143(a)4)

Exterior floors and soffits can meet the component requirements using two methods: install the required R-value of insulation, or demonstrate that the overall U-value of the assembly meets the required U-value (see Section 141(c)4). The U-value calculation allows for calculating the overall insulating qualities of the entire assembly, which includes accounting for the effects of wood or metal framing in the assembly.

The required U-value depends on the type of floor construction: mass and other. The mass floor is distinguished by its heat capacity (HC), which must be greater than 7 (see Heat Capacity discussion in Section 3.1.2G).

Particular note should be taken with this requirement when insulating slab floors that are over unconditioned spaces, such as crawl spaces or parking garages.

Because there are no cavities to accept the insulation, it must be applied either to the underside of the slab or above the slab and beneath the finished floor. There are numerous ways this can be accomplished, but the selection requires careful consideration of the requirements for finishes above or below the insulation.

Table 3-16: Wall Requirements

Nonresidential: Walls					
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
R-value					
Wood or Metal	**13**	**11**	**11**	**13**	**13**
U-value					
Wood Frame	0.084	0.092	0.092	0.084	0.084
Metal Frame	0.182	0.189	0.189	0.182	0.182
Mass/7.0<HC<15.0	0.340	0.430	0.430	0.430	0.430
Mass/15.0<HC	0.360	0.650	0.690	0.650	0.400
Other	0.084	0.092	0.092	0.084	0.084
Residential High-rise: Walls					
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
R-value					
Wood or Metal	**19**	**11**	**11**	**13**	**13**
U-value					
Wood Frame	0.063	0.092	0.092	0.084	0.084
Metal Frame	0.140	0.181	0.181	0.175	0.175
Mass/7.0<HC<15.0	0.340	0.430	0.430	0.430	0.430
Mass/15.0<HC	0.360	0.650	0.690	0.650	0.400
Other	0.063	0.092	0.092	0.084	0.084

E. Windows (§143(a)5)

There are three aspects of the Envelope Component Approach for windows:

1. **Maximum Area**
2. **Maximum U-value**
3. **Maximum Relative Solar Heat Gain**

Under the Envelope Component Approach, the total window area may not exceed 40 percent of the gross wall area for the building (see Section 3.1.2A for the definitions of how these are measured). This maximum area requirement will affect those buildings with very large glass areas, such as automobile showrooms or airport terminals.

Optionally, multiply the length of the display perimeter by six feet in height and use the larger of the product of that multiplication or 40 percent of gross wall area.

Figure 3-10: Floor/Soffit Flowchart

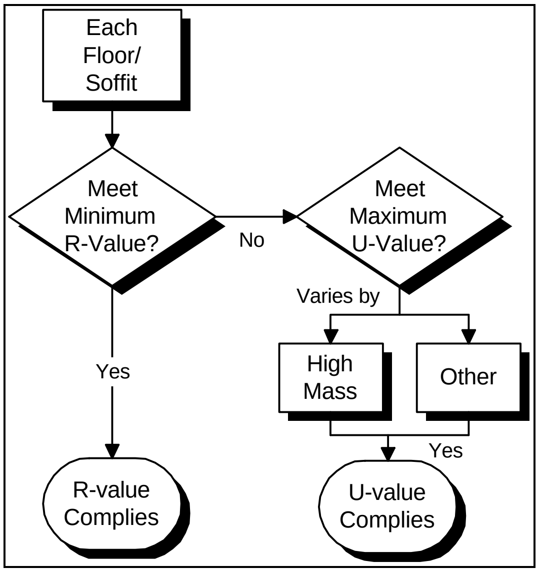


Table 3-17 Floor/Soffit Requirements

Nonresidential: Floor/Soffit					
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
R-value					
Wood or Metal	**19**	**11**	**11**	**11**	**11**
U-value					
Mass/7.0<HC	0.097	0.158	0.158	0.097	0.158
Other	0.050	0.076	0.076	0.076	0.076

Residential High-rise: Floor/Soffit					
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
R-value					
Wood or Metal	**19**	**11**	**11**	**11**	**11**
U-value					
Mass/7.0<HC	0.097	0.158	0.158	0.097	0.097
Other	0.050	0.076	0.076	0.076	0.076
Raised Concrete					
R-value	8	*	*	*	*

Each window or skylight must meet the required U-value and solar heat gain coefficient. The required value for Relative Solar Heat Gain (RSHG) is less stringent (higher) for north-facing windows. The "north" value may also be used for windows in the first floor display perimeter which are prevented from having an overhang because of building code restrictions (such as minimum separation from another building or a property line) (exception to Section 143(a)5.C).

Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the U-value requirement for the climate zone. If the glazing is fully shaded no SHGC requirements apply. However, in situations where demising walls are not fully shaded as the result of skylights or adjacent glazing on an exterior wall, the glazing must have a SHGC equal to that required for north-facing glazing.

Note also that the RSHG limitation allows credit for window overhangs. In order to get credit for an overhang, it must extend beyond both sides of the window jamb by a distance equal to the overhang projection (Section 143(a)5.C.ii). This would occur naturally with a continuous eave overhang, but may require special attention in some designs. See Section 3.1.2J for more information on RSHG.

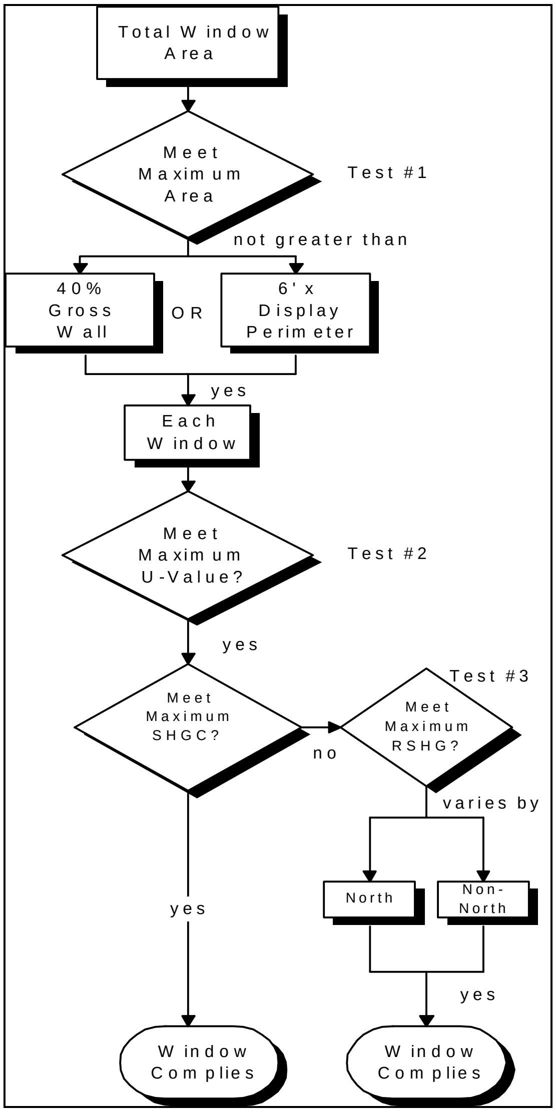
Table 3-18: Window Requirements

Nonresidential: Windows					
	Climate Zones				
	1,16	**2-5**	**6-10**	**11-13**	**14-15**
U-Value*	**0.72**	**1.23**	**1.23**	**0.72**	**0.72**
RelativeSolar					
Heat Gain*					
North	0.77	0.82	0.82	0.77	0.77
Non-North	0.50	0.62	0.62	0.50	0.50

Residential High-rise: Windows					
	Climate Zones				
	1,16	**2-5**	**6-10**	**11-13**	**14-15**
U-Value*	**0.72**	**1.23**	**1.23**	**0.72**	**0.72**
Relative Solar					
Heat Gain*					
North	0.77	0.82	0.82	0.77	0.77
Non-North	0.77	0.82	0.62	0.50	0.50

*The U-value and RSHG must be less than or equal to values shown in the tables.

Figure 3-11: Window Flowchart



F. Skylights (§143(a)6)

As with windows, there are three aspects of the Envelope Component Approach for skylights:

1. **Maximum Area**
2. **Maximum U-value**
3. **Maximum Solar Heat Gain Coefficient**

The area limitation for skylights is based on 5 percent of the gross exterior roof area. This effectively prevents large skylights under the Envelope Component Approach. The limit increases to 10 percent for buildings with an atrium over 55 feet high (see Section 3.1.2A for definition). The 55 foot height is also the height limitation at which the Uniform Building Code requires a mechanical smoke-control system for such atriums UBC Sec. 1715). This means that the 10 percent skylight allowance is not allowed for atriums unless they also meet this smoke control requirement. All skylights must meet the maximum U-value.

Note that skylights are only regulated for SHGC, not RSHG, because skylights cannot have overhangs.

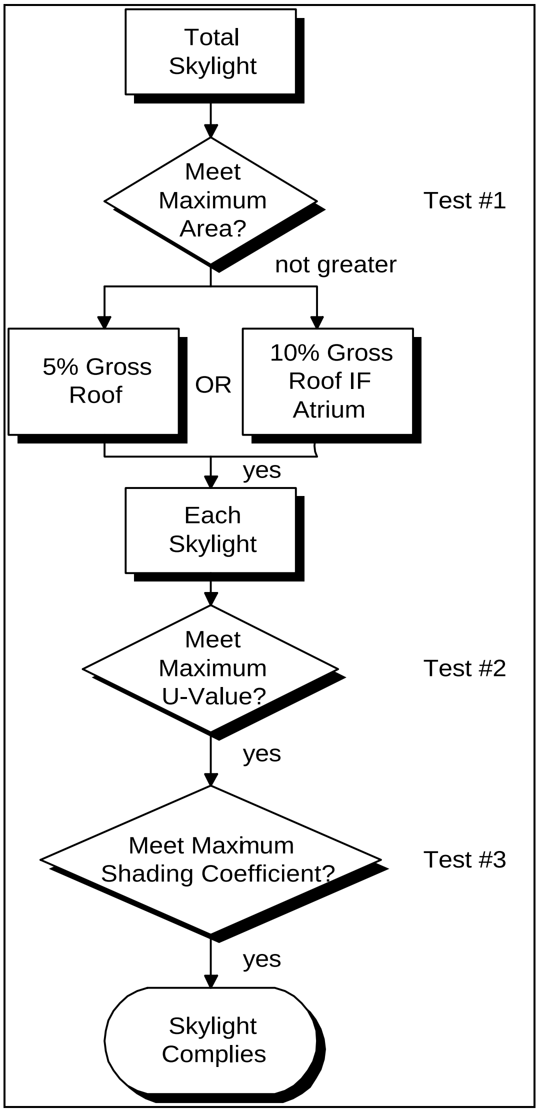
Table 3-19: Skylight Requirements

Nonresidential: Skylights					
	Climate Zones				
	1,16	**2-5**	**6-10**	**11-13**	**14-15**
U-Value*	**0.85**	**1.31**	**1.31**	**0.85**	**0.85**
Solar Heat Gain Coefficient*					
Transparent	0.44	0..61	0..61	0.44	0.44
Translucent	0.70	0.75	0.75	0.70	0.70
Residential: Skylights					
	Climate Zones				
	1,16	**2-5**	**6-10**	**11-13**	**14-15**
U-Value*	**0.85**	**1.31**	**1.31**	**0.85**	**0.85**
Solar Heat Gain Coefficient*					
Transparent	0.44	0.61	0.61	0.44	0.44
Translucent	0.70	0.75	0.75	0.70	0.70

*U-value and SC must be less than or equal to values shown in the table.

For skylights, the standard solar heat gain coefficient (SHGC) differs depending on whether the skylight glazing material is transparent or translucent. A transparent material allows a clear image to be seen when looking at an object through the glazing, while a translucent material will not permit a clear image.

Figure 3-12: Skylight Flowchart



G. Exterior Doors §143(a)7)

Opaque doors have no R-value, U-value or area requirements. Exterior doors are only a part of the compliance process when they are included in the calculation of the gross exterior wall area. Glazing in doors, however, is defined as a window in the *Standards* when it exceeds one-half of the area of the door and must be included in all window calculations.

3.2.3 Prescriptive Overall Envelope Approach (§143(b))

The Overall Envelope Approach is the second prescriptive envelope approach. It offers the greater design flexibility of the prescriptive envelope approaches. It allows the designer to make trade-offs between many of the building envelope components. For example, if a designer finds it difficult to insulate the walls to a level adequate for meeting the wall component U-value requirement, then the insulation level in a roof or floor or the performance of a window component could be increased to offset the under-insulated wall. The same holds true for glazing. If a designer wants to put clear, west-facing glass to enhance the display of merchandise in a show window, it would be possible to use lower SHGC glazing on the other orientations to make up for the increased SHGC on the west.

The Overall Envelope Approach has two parts and both parts must be met: overall heat loss (see Equations 3-2) and overall heat gain (see Equations 3-4). The overall heat loss accounts for the insulating qualities of the building, and sets a maximum rate of conductive heat transfer through the building envelope. The requirements are more stringent in more extreme climate zones than in mild climate zones. The overall heat gain accounts for the area of windows and skylights and their ability to block solar heat gains, thereby reducing cooling loads on the building. These requirements are more stringent in warmer climate zones.

A *standard value* and a *proposed value* are calculated for both the overall heat loss and the overall heat gain using ENV-2: Overall Envelope Method found in Section 3.3.3. These calculations assume that the standard building complies with the requirements of the Envelope Component Approach (also calculated on ENV-2: Overall Envelope Method). The standard values are compared to the proposed values calculated from the actual envelope design. If the proposed values do not exceed the standard values, then the Overall Building Envelope requirements are met.

Table 3-20: Nonresidential Requirements

	Climate Zones				
	1,16	**2-5**	**6-10**	**11-13**	**14-15**
Roof/Ceiling					
R-value Wood or Metal	**19**	**19**	**11**	**19**	**19**
U-value	0.057	0.057	0.078	0.057	0.057
Wall					
R-value Wood or Metal	**13**	**11**	**11**	**13**	**13**
U-value					
Wood Frame	0.084	0.092	0.092	0.084	0.084
Metal Frame	0.182	0.189	0.189	0.182	0.182
Mass/7.0<HC<15.0	0.340	0.430	0.430	0.430	0.430
Mass/15.0<HC	0.360	0.650	0.690	0.650	0.400
Other	0.084	0.092	0.092	0.084	0.084
Floor Soffit					
R-value Wood or Metal	**19**	**11**	**11**	**11**	**11**
U-value					
Mass/7.0<HC	0.097	0.158	0.158	0.097	0.158
Other	0.050	0.076	0.076	0.076	0.076
Windows					
U-Value*	0.72	1.23	1.23	0.72	0.72
Relative Solar Heat Gain*					
North	0.77	0.82	0.82	0.77	0.77
Non-North	0.50	0.62	0.62	0.50	0.50
Skylights					
U-Value*	0.85	1.31	1.31	0.85	0.85
Solar Heat Gain Coefficient*					
Transparent	0.44	0.61	0.61	0.44	0.44
Transparent	0.70	0.75	0.75	0.70	0.70

Table 3-21: High-Rise Residential and Hotel/Motel Guest Room Requirements

	Climate Zones				
	1,16	**2-5**	**6-10**	**11-13**	**14-15**
Roof/Ceiling					
R-value Wood or Metal	**30**	**19**	**19**	**30**	**30**
U-value	0.037	0.051	0.051	0.037	0.037
Wall					
R-value Wood or Metal	**19**	**11**	**11**	**13**	**13**
U-value					
Wood Frame	0.063	0.092	0.092	0.084	0.084
Metal Frame	0.140	0.181	0.181	0.175	0.175
Mass/7.0<HC<15.0	0.340	0.430	0.430	0.430	0.430
Mass/15.0<HC	0.360	0.650	0.690	0.650	0.400
Other	0.063	0.092	0.092	0.084	0.084
Floor Soffit					
R-value Wood or Metal	**19**	**11**	**11**	**11**	**11**
U-value					
Mass/7.0<HC	0.097	0.158	0.158	0.097	0.097
Other	0.050	0.076	0.076	0.076	0.076
Raised Concrete R-value	8	**	**	**	**
Windows					
U-Value*	0.72	1.23	1.23	0.72	0.72
Relative Solar Heat Gain*					
North	0.77	0.82	0.82	0.77	0.77
Non-North	0.77	0.82	0.62	0.50	0.50
Skylights					
U-Value*	0.85	1.31	1.31	0.85	0.85
Solar Heat Gain Coefficient*					
Transparent	0.44	0.61	0.61	0.44	0.44
Transparent	0.70	0.75	0.75	0.70	0.70

*** U-values, RSHG and SHGC must be less than or equal to values shown in the above tables**

**** R-8 in climate zones 1, 2, 11, 13, 14, and 16; R-4 is required in climate zones 12 and 15; and R-0 in climate zones 3 –10.**

Associated with the increased design flexibility afforded by the Overall Envelope Approach is an increase in complexity of the calculations when demonstrating compliance. Special attention must be given to the calculations because the effects of all the envelope components are interrelated. Changing any one component may prevent the overall envelope from complying. Improvements to one or more of the other components will be needed to bring the envelope into compliance.

Equation 3-2 Standard Building Heat Loss

$$HL_{std} = \sum_{i=1}^{nW} \left(A_{Wi} \times U_{Wi_{std}} \right) + \sum_{i=1}^{nF} \left(A_{Fi} \times U_{Fi_{std}} \right) + \sum_{i=1}^{nR} \left(A_{Ri} \times U_{Ri} \times U_{Ri_{std}} \right) + \sum_{i=1}^{nG} \left(A_{Gi} \times U_{Gi_{std}} \right) + \sum_{i=1}^{nS} \left(A_{Si} \times U_{Si_{std}} \right)$$

Refer to Section 143 of the 1998 Energy Efficiency Standards for equation definitions

A. Overall Heat Loss

There are two parts to the Overall Heat Loss calculation. The first is to calculate the Standard Building Heat Loss; this becomes the standard that must be met. The second is to calculate the Proposed Building Heat Loss, which is compared to the standard to show that it does not exceed the Standard Building Heat Loss.

There are three steps to calculating the Standard Building Heat Loss:

Step 1 - Calculate areas of each type of envelope assembly (walls, windows, roofs, etc.). If glazing is too large or small, areas may require adjustment as directed on the ENV-2.

Step 2 - Determine allowed U-values from Tables 3-20 and 3-21.

Step 3 - Multiply and add to get Standard Building Heat Loss.

Each step will be discussed in turn.

Calculate Areas

First, identify each type of assembly in the building envelope. In a complex building, there could be many. Assemblies are different if they have different materials or thermal properties. For example, a steel stud framed wall with a 1" stucco exterior would be different from a steel stud framed wall with 4" brick cladding.

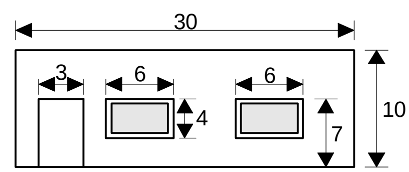
Next, calculate the areas of each assembly. All dimensions are taken at the exterior surface of the assembly. The sum of all the vertical surface areas is the gross exterior wall area (walls, windows, doors). The exterior wall area is the opaque wall area only (no doors). The window wall ratio is the total window area in the gross exterior walls, divided by the gross exterior wall area.

In the case of windows, the area is based on the rough opening dimensions. For most buildings, the actual window area is used to calculate the Standard Building Heat Loss.

Example 3-2: Area Calculation

Question

How is exterior wall area calculated for the following wall (dimensions in feet)?



Answer

The gross exterior wall area is 30 x 10 = 300 ft^2. The door area is 3 x 7 = 21 ft^2. The window areas are 6 x 4 = 24 ft^2 each, or 48 ft^2 total. The exterior wall area is the gross minus doors and windows, or 300 ft^2 — 21 ft^2 — 48 ft^2 = 231 ft^2.

Adjust Areas

When the window wall ratio is less than 10 percent or more than 40 percent, an adjusted window area is used to calculate the Standard Building Heat Loss.

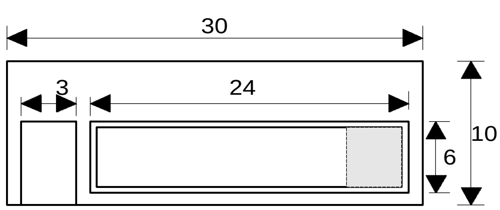
The first adjustment is for buildings with very little window area. The *Standards* allow for a minimum of 10 percent window wall ratio in calculating the standard envelope heat loss ("A_{Gi}" of Equation 3-2). If the actual window wall ratio is less than 10 percent, then an area equal to 10 percent of the gross exterior wall area is used for the standard building.

The second adjustment is for buildings with very large window area. If the actual window wall ratio is greater than 40 percent, then an area equal to 40 percent of the gross wall area is used to calculate the Standard Building Heat Loss. Alternatively, for buildings with substantial display perimeter areas (see 3.1.2A), an area equal to six feet high by the length of the display perimeter is calculated. If this value is greater than 40 percent of the gross exterior wall area, then it is used in the standard envelope heat loss calculation ("A_{Gi}" of Equation 3-2)

Example 3-3: Glazing Area Adjustments

Question

What is the window wall ratio (WWR) for the following wall (dimensions in feet)? How is the window and wall area adjusted under the overall envelope approach?



Answer

The gross exterior wall area is 30 x 10 = 300 ft². The window area is 24 x 6 = 144 ft². The WWR is 144 / 300 = 0.48, or 48 percent. The exterior wall area is 300 — 144 = 156 ft². The window area must be adjusted downward to 40 percent of the gross exterior wall area, or 0.40 x 300 = 120 ft². This is a window area reduction of 144 —120 = 24 ft². The exterior wall area must be increased by the same amount to 156 + 24 = 180 ft² (as shown by shaded area in sketch above).

If either of these adjustments is made to the standard window area, the exterior wall area is also adjusted (see Example 3-2). Skylights are treated similarly ("A_{Si}" of Equation 3-2). In most cases, the actual skylight area will be used to calculate the standard envelope heat loss. If the skylight shape is three-dimensional (not flat), then the area is the actual surface area, not the opening area (see Section 3.1.2A). If the skylight area is larger than 5 percent of the gross exterior roof area (roof doors not included for the standard building), then an area equal to 5 percent of the roof area is used. Alternatively, if the building has an atrium over 55 feet high, then the allowance for skylights is increased to 10 percent (or the actual skylight area if less than 10 percent of the gross roof area).

Determine Allowed U-values

The allowed U-values are taken from Tables 3-20 and 3-21, depending on the occupancy type. These are the same values discussed under the Envelope Component Approach in the previous Section 3.2.2. It is necessary to differentiate wall assembly types and floor/soffit assembly types. The U-value requirements depend on framing type and heat capacity of the wall or the floor/soffit. In the case of heavier construction assemblies, the heat capacity (see Section 3.1.2G) must be calculated before the allowed U-value can be determined.

Multiply and Add

Once the areas and allowed U-values are determined for each assembly, then the Standard Building Heat Loss can be calculated. For each assembly, the U-value (U) and area (A) are multiplied together; the result is known as the *UA product* for the assembly. If any of the areas were adjusted, then the adjusted areas are used in this calculation. These UA products are added to obtain the total UA product for the building, which is the Standard Building Heat Loss.
The Standard Building Heat Loss has units of Btu/hr-°F, and it describes the amount of heat lost per hour through the building envelope for every degree Fahrenheit of temperature difference between inside and outside, under steady state heat flow conditions.

Equation 3-3: Proposed Building Heat Loss

$$HL_{prop} = \sum_{j=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}}\right) + \sum_{j=1}^{nF}\left(A_{Fj} \times U_{Fj_{prop}}\right) + \sum_{j=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}}\right) + \sum_{j=1}^{nG}\left(A_{Gj} \times U_{Gj_{prop}}\right) + \sum_{j=1}^{nS}\left(A_{Sj} \times U_{Sj_{prop}}\right)$$

Refer to Section 143 of the 1998 Energy Efficiency Standards for equation definitions.

Once the Standard Building Heat Loss rate is determined, the proposed design's heat loss rate can be calculated and the two can be compared. If the proposed heat loss rate does not exceed the standard, then the envelope complies with the heat loss criteria.

The proposed heat loss is calculated the same as the standard, except that the actual areas and U-values of each assembly are used without adjustment. The actual U-values are calculated as described in section 3.1.2 C-F. It is not necessary to calculate the U-value of opaque doors, as they are ignored in the overall heat loss calculations. Any glazing in doors, however, is considered a window and must be included in all window calculations.

The UA product is calculated for each surface, and these are totaled to arrive at the Proposed Building Heat Loss. It has the same units and meaning as the Standard Building Heat Loss (see above).

For a complete example of how the Standard Building Heat Loss and Proposed Building Heat Loss are calculated and compared using the ENV-2 form (see Section 3.3.2).

B. Overall Heat Gain

As with the overall heat loss, there are two parts to the Overall Heat Gain calculation. The first part is to calculate the Standard Building Heat Gain; this becomes the standard that must not be exceeded.

The second part is to calculate the Proposed Building Heat Gain; compare this to the standard and show that the proposed heat gain does not exceed the standard heat gain.

Equation 3-4: Standard Building Heat Gain

$$HG_{std} = \sum_{i=1}^{nW}\left(A_{Wi} \times TF_i\right) + \sum_{i=1}^{nF}\left(A_{Fi} \times U_{Fi_{std}} \times TF_i\right) + \sum_{i=1}^{nR}\left(A_{Ri} \times U_{Ri_{std}} \times TF_i\right) + \sum_{i=1}^{nG}\left(A_{Gi} \times U_{Gi_{std}} \times TF_i\right) + \sum_{i=1}^{nS}\left(A_{Si} \times U_{Si_{std}} \times TF_i\right) + \sum_{i=1}^{nG}\left(WF_{Gi} \times A_{Gi_{std}} \times RSHG_{Gi_{std}}\right) \times SF + \sum_{i=1}^{nS}\left(WF_{Si} \times A_{Si_{std}} \times SHGC_{Si_{std}}\right) \times SF$$

Refer to Section 143 of the 1998 Energy Efficiency Standards for equation definitions.

There are four steps to calculating the Standard Building Heat Gain:

Step 1 - Calculate the area and determine the U-value and temperature factor (Table 3-22) of each type of envelope assembly (walls, windows, roofs, etc.) [Same values as heat loss equations.] Window areas may require adjustment if too large or small.

Step 2 - Determine RSHG for north and non-north orientations, and SHGC for skylights (as per climate zone, occupancy and type); values are taken from Tables 3-20 and 3-21.

Step 3 - Determine the weighting factors and solar factors for each orientation (as per climate zone) from Table 3-23.

Step 4 - Multiply and add to get Standard Building Heat Gain.

Each step will be discussed in turn.

Calculate Areas

The total area of envelope features and glazing and corresponding U-values were determined earlier for the Standard Building Heat Loss calculation. A temperature factor (Table 3-22) is applied. Window area was adjusted when it was too large or too small for the standard area. This same total is used for the Standard Building Heat Gain Calculation, except that it is further broken down by orientation. Each window is assigned to the nearest cardinal orientation: east, west, north and south (see Section 3.1.2). A solar factor (Table 3-22) is applied to window and skylight areas.

As in the heat loss calculation, the window areas are calculated by the rough opening dimensions.

Adjust Areas

If the total window area was adjusted in the standard heat loss calculation, a similar adjustment is made here, except that it is applied to each orientation. For example, if the proposed window wall ratio is 50 percent, then the window must be reduced to 40 percent for the standard reduction. This translates to the glazing area on each orientation being reduced by 20 percent for the standard heat gain calculation.

Determine RSHG and SHGC

The values for RSHG and SHGC are found in Tables 3-20 and 3-21. For windows, the standard relative solar heat gain (RSHG) differs depending on whether or not the window is north-facing (see Sections 3.1.2A, I and J for definitions). For skylights, the standard solar heat gain coefficient (SHGC) differs depending on whether the skylight glazing material is transparent or translucent. A transparent material allows a clear image to be seen when looking at an object through the glazing, while a translucent material will not permit a clear image.

The values of RSHG and SHGC also differ by climate zone. For the milder climate zones 2–10, higher values are allowed.

For the Standard Building Heat Gain calculation, the values of RSHG and SHGC are simply taken from the tables and entered into the calculations.

Example 3-4: RSHG Determination

Question
What is the RSHG value for an east-facing window in an office building in climate zone 8? .
Answer
0.62 (Table 3-20)

Determine Temperature Factor

The temperature factor considers the effects of solar radiation striking opaque surfaces. The appropriate values are taken from Table 3-22 and entered into the calculations.

Table 3-22
Temperature and Solar Factors

Climate Zone	TEMPERATURE FACTOR (TF) Envelope Construction (Mass) Light	Medium	Heavy	SOLAR FACTOR (SF) (Btu/hr-ft²)
1	14	3	1	128
2	40	30	28	126
3	28	18	16	126
4	32	22	20	125
5	27	17	15	124
6	28	18	16	123
7	27	17	15	123
8	33	23	21	123
9	42	31	29	123
10	45	35	33	123
11	49	38	36	127
12	45	34	32	126
13	45	35	33	125
14	52	42	40	125
15	55	45	43	123
16	34	23	21	128

Light Mass: Heat Capacity < 7 Btu/ft²-°F
Medium Mass: Heat Capacity >= 7 and <15 Btu/ft²-°F
Heavy Mass: Heat Capacity >= 15 Btu/ft²-°F

Determine Weighting Factors

Weighting factors in the heat gain equations account for the variation in solar radiation striking windows and skylights by orientation and climate zone. The appropriate values are taken from Table 3-23 and entered into the calculations.

Table 3-23: Glazing Orientation Weighting Factors

Climate Zone	1,16	2-5	6-10	11-13	14, 15
North	0.63	0.52	0.34	0.42	0.67
East	1.14	1.05	1.02	1.27	1.08
South	0.99	1.24	1.31	1.14	1.12
West	1.24	1.19	1.34	1.17	1.13
Skylight	2.54	2.74	2.30	2.54	2.45

Example 3-5: Determining Weighting Factors

Question

What is the weighting factor for a south-facing window in climate zone 12?

Answer

1.14 (Table 3-22)

Determine Solar Factor

The solar factor is used to account for solar radiation striking glazed surfaces. The appropriate values are taken from Table 3-22 and entered into the calculations.

Multiply and Add

Once the areas and the allowed RSHG, SHGC and weighting factor are determined for each glazing orientation, then the Standard Building Heat Gain can be calculated. For each window orientation, the adjusted area is multiplied by the RSHG value and the weighting factor. For each type of skylight (transparent and translucent), the adjusted areas are multiplied by the SHGC value and the weighting factor. If the window or skylight area was adjusted, the adjusted areas are used in this calculation. All of these products are added to obtain the Standard Building Heat Gain.

Once the Standard Building Heat Gain rate is determined, the proposed design heat gain rate can be calculated and the two can be compared. If the proposed heat gain rate does not exceed the standard, then the envelope complies with the heat gain criteria.

The proposed heat gain is calculated the same as the standard, except that the actual areas for each orientation, and the actual RSHG and SHGC are used. The determination of actual SHGC and RSHG are described above in Sections 3.1.2I and 3.1.2J.

For the windows on each orientation, the actual area, SHGC, overhang factor and weighting factor are multiplied together. For skylights, the actual area, SHGC and weighting factor are multiplied. These are summed to obtain the Proposed Building Heat Gain.

Equation 3-5: Proposed Building Heat Gain

$$
\begin{aligned}
HG_{prop} = &\sum_{i=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}} \times TF_j\right) + \\
&\sum_{i=1}^{nF}\left(A_{Fj} \times U_{Fj_{prop}} \times TF_j\right) + \\
&\sum_{i=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}} \times TF_j\right) + \\
&\sum_{i=1}^{nG}\left(A_{Gj} \times U_{Gj_{prop}} \times TF_j\right) + \\
&\sum_{i=1}^{nS}\left(A_{Sj} \times U_{Sj_{prop}} \times TF_j\right) + \\
&\sum_{i=1}^{nG}\left(WF_{Gj} \times A_{Gj} \times SHGC_{Gj_{prop}} \times OHF_j\right) \times SF + \\
&\sum_{i=1}^{nS}\left(WF_{Sj} \times A_{Sj} \times SHGC_{Sj_{prop}}\right) \times SF
\end{aligned}
$$

Refer to Section 143 of the 1998 Energy Efficiency Standards for equation definitions.

For an example of how the Standard and Proposed Building Heat Gain are calculated and compared using the ENV-2 form (see Section 3.3.3).

3.2.4 Performance Approach

Under the performance approach, the energy use of the building is modeled using an energy budget generated by a computer program approved by the Energy Commission (see Appendix E). This section presents some basic details on the modeling of building envelope components. *Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program.* All computer programs, however, are required to have the same basic modeling capabilities. A discussion on the performance approach, and fixed and restricted inputs, is included in Section 6.1.

A. Modeling Envelope Components

The following modeling capabilities are required by all approved nonresidential computer programs. These modeling features affect the thermal loads seen by the HVAC system model.

Opaque Surface Mass Characteristics

Heat absorption, retention and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled. Typical inputs are thickness, density, specific heat and conductivity. See Section 3.1.2G for determining the heat capacity of materials.

Opaque Surface Heat Transfer

Heat gains and heat losses are modeled through opaque surfaces of the building envelope. The following inputs or acceptable alternative inputs are used by this modeling capability:

- Surface areas by opaque surface type. Section 3.1.2A discusses determining the area of opaque surfaces.
- Surface orientation and slope. Section 3.2.1A discusses how slope affects wall and roof/ceiling definitions.
- Thermal conductance of the surface. Section 3.1.2C through G discusses determining the U-value of various assemblies.
- Surface absorptance. Surface absorptance is a restricted input. Section 6.1.3A discusses fixed and restricted modeling assumptions.

Glazing Heat Transfer

Heat transfer through all glazed (transparent or translucent) surfaces of the building envelope are modeled using the following inputs:

- Glazing areas. Section 3.1.2A discusses determining the area of windows and skylights.
- Glazing orientation and slope. Section 3.1.2A discusses how slope affects window and skylight definitions.
- Glazing thermal conductance. Section 3.1.2H discusses how to determine the fenestration U-value.
- Glazing solar heat gain coefficient. Section 3.1.2I. discusses how to determine the solar heat gain coefficient of glazing.

Overhangs

Approved computer programs are able to model overhangs. Typical inputs are overhang projection, height above window, window height and the overhang horizontal extension past the edge of the window. If the overhang horizontal extension (past the window jambs) is not an input, then the program must assume that the extension is zero (i.e., overhang width is equal to window width) which results in no benefits from the overhang.

Interzone Surfaces

Heat transfer modeled through all surfaces separating different space conditioning zones may be modeled with inputs such as surface area, surface tilt and thermal conductance. Thermal mass characteristics may be modeled using the thickness, specific heat, density and types of layers that comprise the construction assembly.

3.2.5 Alterations

Alterations to the envelope of an existing conditioned space have the following options for showing compliance:

Option 1. Show that the overall heat gain and heat loss of the building is not increased. This can be demonstrated on form ENV-2, Overall Envelope Method, Part 2 of 5 and Part 3 of 5 by showing the heat gain and heat loss for the altered component(s) before and after the alteration; or

> NOTE:
>
> For alterations that include an increase in glazing area, this compliance option is not practical. This is because the equation for heat gain considers only glazing surfaces, however, neither heat gain nor loss can increase with this option.

Option 2. Meet current prescriptive envelope requirements for the altered component; or

> NOTE:
>
> The prescriptive solar heat gain coefficient requirements do not apply to fenestration repaired, replaced, or up to 50 square feet of new glass.

Option 3. Use an approved computer program to show compliance with an energy budget for the altered space; or

Option 4. Use an approved computer program to show that the energy use of the entire building is what it would be if the remainder of the building was unaltered and the altered space complied with its energy budget ("existing plus alteration"). This fourth option involves four steps and three separate computer runs:

Step 1. Model the building before any alterations or additions to determine the energy use of the existing building (use the value referred to as the "proposed" energy use).

Step 2. Model the new or altered space to determine the energy budget ("standard" design) of the alteration or addition alone.

Step 3. Calculate the energy budget for the entire building as indicated in Equation 3-6.

Equation 3-6: Energy Use Goal

$$\frac{(A_e \times PD_e) + (A_a \times SD_a)}{A_{e+a}} = \text{Energy Use Goal}$$

where:

A_e = Area of the existing entire building before the proposed addition/alteration (from Step 1. above)

PD_e = Proposed design of the existing entire building before the proposed addition/alteration (from Step 1. above)

A_a = Area of the proposed addition/alteration (from Step 2. above)

SD_a = Standard design for the proposed addition/alteration (from Step 2, above)

A_{e+a} = Area of the entire building after the proposed addition/ alteration

Step 4. Model the entire building, including the proposed addition/ alteration, along with any improvements to the existing building. If the proposed design is less than or equal to the energy use goal (from Step 3. above), the addition or alteration complies.

3.3 ENVELOPE PLAN CHECK DOCUMENTS

At he time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the recommended forms and procedures for documenting compliance with the envelope requirements of the *Standards.* It does not describe the details of the requirements; these are presented in Section 3.2 Envelope Design Procedures. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the building department plan checkers who are examining documents for compliance with the *Standards.*

The use of each form is briefly described below, then complete instructions for each form are presented in the following subsections.

ENV-1: Certificate of Compliance
This form should be required for every job, and it is required to appear *on the plans. (Title 24, Part 1, Section 10-103 of the California Code of Regulations.)*

ENV-2: Envelope Component Method, Overall Envelope Method, or Performance Method
One of these three versions should be part of every envelope compliance submittal. Choose the version that corresponds to the compliance method selected for the job.

ENV-3: Metal-Framed Assembly, Masonry Assembly, or Proposed Wood Frame Assembly
One of these forms should be submitted for each construction assembly in the building that does not use an Energy Commission default U-value. The version is chosen to match the type of assembly. If the assembly is something other than a metal-framed or masonry assembly, the Proposed Construction Assembly version of ENV-3 should be used.

3.3.1 ENV-1: Certificate of Compliance

The ENV-1 Certificate of Compliance form has two parts. Both parts must appear on the plans (usually near the front of the architectural drawings). A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the Energy Commission's forms), provided the information is the same and in similar format.

A. ENV-1 Part 1

Project Description

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.
2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.
3. **PROJECT ADDRESS** is the address of the project as shown on the plans and known to the building department.
4. **PRINCIPAL DESIGNER - ENVELOPE** is the person responsible for the preparation of the building envelope plans, and who signs the STATEMENT OF COMPLIANCE (see below). The person's telephone number is given to facilitate response to any questions that arise.
5. **DOCUMENTATION AUTHOR** is the person who prepared the energy compliance documentation and who signs the STATEMENT OF COMPLIANCE. The person's telephone number is given to facilitate response to any questions that arise.
6. **ENFORCEMENT AGENCY USE** is reserved for building department record keeping purposes.

General Information

1. **DATE OF PLANS** is the last revision date of the plans. If the plans are revised after this date, it may be necessary to re-submit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.
2. **BUILDING CONDITIONED FLOOR AREA** has specific meaning under the energy *Standards*. Refer to Section 2.1.2A for a discussion of this definition.
3. **CLIMATE ZONE** is the official climate zone number where the building is located. Refer to California Climate Zone Description (Appendix C) for a listing of cities and their climate zones.
4. **BUILDING TYPE** is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the *Nonresidential Standards* are designated "Non

residential" here. It is possible for a building to include more than one building type, in which case check all applicable types here. See Section 2.1.2B for the formal definitions of these occupancies.

5. **PHASE OF CONSTRUCTION** indicates the status of the building project described in the documents. Refer to Section 2.2 for detailed discussion of the various choices.

   a. **NEW CONSTRUCTION** should be checked for all new buildings (see Section 2.2.6), newly conditioned space (see Section 2.2.2) or a stand-alone addition submitted for envelope compliance.

   b. **ADDITION** should be checked for an addition which is not treated as a stand-alone building, but which uses existing plus addition performance compliance, as described in Section 2.2.5.

   c. **ALTERATION** should be checked for alterations to existing building envelopes. See Section 2.2.4.

   d. **UNCONDITIONED** should be checked when the building is not intended as conditioned space, or when the owner chooses to defer demonstrating envelope compliance until such time as the space conditioning system permit application is submitted. See Section 2.2.1 for a full discussion. The building department may require the owner to file an affidavit declaring the building to be unconditioned and acknowledging that all the *Standards* requirements must be met when the building is conditioned.

6. **METHOD OF COMPLIANCE** - indicate which method is being used and documented with this submittal:

   a. **COMPONENT** for the Envelope Component Method

   b. **OVERALL ENVELOPE** for the Overall Envelope Method

   c. **PERFORMANCE** for the Performance Method

Statement of Compliance

The Statement of Compliance is signed by the person responsible for preparation of the plans for the building and the documentation author. This principal designer is also responsible for the energy compliance documentation, even if the actual work is delegated to someone else (the Documentation Author described above). It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the *Business and Professions Code* (based on the edition in effect as of July 1998), referenced on the Certificate of Compliance are provided below:

5537. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the

responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. *This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.*

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. *This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:*

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

6737.3. *A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does* *perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.*

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person

Envelope Mandatory Measures

The Mandatory Measures should be incorporated into the construction documents. The designer may use whatever format is most appropriate for specifying the mandatory measures in the plan set. In general, this will take the form of a note block near the front of the set, possibly with cross-references to other locations in the plans where measures are specified. A sample, generic envelope mandatory measures note block is shown in Example 3-6. This is offered as a starting point for designers; it should be incorporated into the organization of the plan set and modified to be specific to the building design.

Example 3-6: Sample Notes Block - Envelope Mandatory Measures

Nonresidential Energy Standards Compliance (Title 24, Part 6, Ch. 1)

Envelope Mandatory Measures

- **Installed Insulating Material** shall have been certified by the manufacturer to comply with the California Quality Standards for Insulating Material.
- **All Insulating Materials** shall be installed in compliance with the flame spread rating and smoke density requirements of Sections 2602 and 707 of the UBC.
- **All Exterior Joints** and openings in the building envelope that are observable sources of air leakage shall be caulked, gasketed, weather-stripped or otherwise sealed.
- **Site Constructed Doors, Windows and Skylights** shall be caulked between the unit and the building, and shall be weather-stripped (except for unframed glass doors and fire doors).
- **Manufactured Doors and Windows** installed shall have air infiltration rates certified by the manufacturer per Section 116(a)1. Manufactured fenestration products must be labeled for U-value according to NFRC procedures.
- **Demising Wall Insulation** (R-11) shall be installed in all opaque portions of framed walls (except doors).

B. ENV-1 Part 2

The information on Part 2 summarizes the information about the building envelope that can be readily verified by the building department field inspector. This form should be included on the plans. Alternatively, the information may be incorporated into construction assembly and glazing schedules on the plans, provided it is complete and in substantially the same format as this form.

Opaque Surfaces

1. **SURFACE TYPE** - provide a name or designator for each unique type of opaque surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

2. **CONSTRUCTION TYPE** - list the general type of construction for each opaque surface type. The entry should be descriptive, as it is used by the field inspector to distinguish between the various assemblies.

3. AREA - list the gross surface area of the surface type.

4. U-VALUE - list the U-value of the surface type.

5. AZIMUTH - the plan Azimuth is determined by an observer standing outside the building looking at the front elevation.

6. TILT – Tilt of opaque surface is expressed in terms of degrees, 0=horizontal facing up, 90=vertical, 180=horizontal facing down.

7. SOLAR GAINS Y/N - indicate Y[es] for opaque surfaces that will be receive direct or indirect sunlight.

8. FORM 3 REFERENCE - list the name used on the ENV-3 form for the proposed assembly (whether or not it is a default value).

9. **LOCATION/COMMENTS** - use to provide further description for each surface type. Again, it should be descriptive to assist in locating and inspecting the assembly.

10. **NOTE TO FIELD** - this column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Fenestration Surfaces

1. **FENESTRATION TYPE** - provide a designator for each unique type of window.(e.g., window, skylight).

2. **AREA** - indicate the total square feet of all of the fenestration with the same characteristics.

3. **U-VALUE** - indicate the maximum U-value for windows using either manufacturer's data or the Energy Commission's default U-values (see Table 3-10).

4. **AZIMUTH** - the plan Azimuth is determined by an observer standing outside the building looking at the front elevation.

5. **SHGC** - list the solar heat gain coefficient (SHGC) of the fenestration product using either manufacturer's data or the Energy Commission's default SHGC values (see Table 3-11).

6. **GLAZING TYPE** - indicate the general type of primary glazing material for the window (clear, tinted, reflective, low-e, etc.).

7. **LOCATION/COMMENTS** - use to provide further description for each surface type. It should be descriptive enough to assist in locating and inspecting the fenestration.

8. **NOTE TO FIELD** - this column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Exterior Shading

1. Fenestration # - list the designation on the plans for the fenestration with exterior shading.

2. Exterior Shade Type - list the type of exterior shading, limited to devices permanently attached to the building (e.g., shade sceens), or structural components of the building (i.e., overhangs and fins). Manually operable shading devices cannot be modeled.

3. SC - list the shading coefficient of the shading device.

4. Window - when the shading type is an overhang or fin list the height and width (in feet) of the window.

5. Overhang - for overhangs being used to achieve compliance with prescriptive envelope requirements, list the dimensions (in feet) of the overhang:

   a. Length - is the distance (in feet) the overhang projects out from the building facade.

   b. Height - is the distance, in feet, from the bottom of the window to the bottom of the overhang. To qualify for credit, the bottom of the overhang must be no more than two vertical feet higher than the top of the window (window head).

c. LExt. and RExt. - is the length the overhang extends beyond the window on the left and right sides. Credit for an overhang may be taken only if the overhang extends beyond both sides of the window jamb a distance equal to the overhang length.

6. Left Fin – dimension which describe side fins to the left of the fenestration in feet-inches.

   a. Distance along the wall from the left edge of the glazing.

   b. Length of the left fin from the wall, from the length field in the fins.

   c. Height of the left fin from the bottom of the wall to the top of the fin.

7. Right Fin – dimension which describe side fins to the right of the fenestration in feet-inches.

   a. Distance along the wall from the right edge of the glazing.

   b. Length of the right fin from the wall, from the length field in the fins.

   c. Height of the right fin from the bottom of the wall to the top of the fin.

Notes to Field

This space is for building department use only. It may be used by the plan checker to continue or elaborate on notes elsewhere on the form.

C. Sample Form: ENV-1 Certificate of Compliance

CERTIFICATE OF COMPLIANCE (Part 1 of 2) ENV-1

PROJECT NAME		DATE
PROJECT ADDRESS		
PRINCIPAL DESIGNER-ENVELOPE	TELEPHONE	Building Permit #
DOCUMENTATION AUTHOR	TELEPHONE	Checked by/Date Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA	CLIMATE ZONE

BUILDING TYPE	☐ NONRESIDENTIAL	☐ HIGH RISE RESIDENTIAL		☐ HOTEL/MOTEL GUEST ROOM
PHASE OF CONSTRUCTION	☐ NEW CONSTRUCTION	☐ ADDITION	☐ ALTERATION	☐ UNCONDITIONED (file affidavit)
METHOD OF ENVELOPE COMPLIANCE	☐ COMPONENT	☐ OVERALL ENVELOPE		☐ PERFORMANCE

STATEMENT OF COMPLIANCE

This Certificate of compliance lists the building features and performance specifications need to comply with Title 24, Parts 1 and 6 of the California Code of Regulations. This certificate applies only to building envelope requirements.

The documentation preparer hereby certifies that the documentation is accurate and complete.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Envelope Designer hereby certifies that the proposed building design represented in this set of construction documents is consistent with the other compliance forms and worksheets, with the specifications, and with any other calculations submitted with this permit application. The proposed building has been designed to meet the envelope requirements contained in sections 110, 116 through 118, and 140, 142, 143 or 149 of Title 24, Part 6.

Please check one:

☐ I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for its preparation; and that I am licensed in the State of California as a civil engineer or mechanical engineer, or I am a licensed architect.

☐ I affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code by section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ I affirm that I am eligible under Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described as exempt pursuant to Business and Professions Code Sections 5537, 5538 and 6737.1.

(These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

PRINCIPAL ENVELOPE DESIGNER-NAME	SIGNATURE	DATE	LIC. #

ENVELOPE MANDATORY MEASURES

Indicate location on plans of Note Block for Mandatory Measures ______________________________

INSTRUCTIONS TO APPLICANT

For Detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the Nonresidential Manual published by the California Energy Commission.

ENV-1: Required on plans for all submittals. Part 2 may be incorporated in schedules on plans.

ENV-2: Used for all submittals; choose appropriate version depending on method of envelope compliance.

ENV-3: Optional. Use if default U-values are not used. Choose appropriate version for assembly U-value to be calculated.

CERTIFICATE OF COMPLIANCE (Part 2 of 2) ENV-1

PROJECT NAME	DATE

OPAQUE SURFACES

Surface Type	Construction Type (e.g., Block, Wood, Metal)	Area	U-Value	Azimuth	Tilt	Solar Gains Y/N	Form 3 Reference	Location/Comments (e.g., Suspended Ceiling, Demising, etc.)	NOTES TO FIELD - For Building Dept. Use Only
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			

FENESTRATION SURFACES

Fenestration Type	Area	U-Value	Azimuth	SHGC	Glazing Type	Location / Comments	NOTES TO FIELD - For Bldg. Dept. Use Only

EXTERIOR SHADING

Fenestration #	Exterior Shade Type	SHGC	Window		Overhang				Left Fin			Right Fin		
			Height	Width	Length	Height	LExt.	RExt.	Dist.	Length	Height	Dist.	Length	Height

NOTES TO FIELD - For Building Department Use Only

3.3.2 ENV-2: Envelope Component Method

This version of ENV-2 should be used only when the envelope is shown to comply using the Envelope Component Method.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Window Area Calculation

This calculation determines whether the window area for the building exceeds the allowable maximum for the Envelope Component Method.

1. **GROSS WALL AREA -** refer to Section 3.1.2A for definition and discussion. This is multiplied by 0.4 to determine the 40% area for glazing limits.

2. **DISPLAY PERIMETER** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 6 to determine the display perimeter area for glazing limits.

3. **MAXIMUM ALLOWABLE WINDOW AREA** - the greater of the previous two calculation results is the maximum window area allowed under the Envelope Component Method.

4. **PROPOSED WINDOW AREA** - the total area of proposed windows shown on the plans is entered here. See Section 3.1.2A for definition and discussion. If this area is greater than the Maximum Allowable Window Area, then the Envelope Component Method may not be used.

B. Skylight Area Calculation

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the Envelope Component Method.

1. **ATRIUM HEIGHT -** refer to Section 3.1.2A for definition and discussion.

2. **ALLOWED %** - Depending on the atrium height, the allowed percentage of roof area for skylights may be 5% (0.05) or 10% (0.1).

3. **GROSS ROOF AREA** - Gross roof area - refer to Section 3.1.2.A for definition and discussion.

4. **ALLOWABLE SKYLIGHT AREA** - Allowed Skylight Area - the maximum allowable skylight area is the product of the previous two numbers.

5. **ACTUAL SKYLIGHT AREA** - Actual Skylight Area - the total area of proposed skylights shown on the plans is entered here. See Section 3.1.2A for definition and discussion. If this area is greater than the Maximum Allowed Skylight Area, then the Envelope Component Method may not be used.

C. Opaque Surfaces

1. **ASSEMBLY NAME** - provide a name or designator for each unique type of opaque surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

2. **TYPE** - provide the type of assembly as described in Tables 3-20 and 3-21 (e.g. wood-frame wall, other floor/soffit, etc.). If the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to

submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly shown in Table B-7, e.g. R.30.2 x 10.16, in the "Opaque Surfaces" category.

3. **HEAT CAPACITY** - see Section 3.1.2G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies, but if it is blank, the lower U-value requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

4. **INSULATION R-VALUE -** This section is used for assemblies that are shown to comply by this option under the Envelope Component Method. If the Assembly U-value option is used, this space may be left blank. The PROPOSED value is the R-value for the insulation product alone, not the total R-value for the assembly. It must be consistent with the R-value called out on the ENV-1 form. The MIN. ALLOWED value is taken from Tables 3-20 and 3-21.

5. **ASSEMBLY U-VALUE** - This section is used for assemblies that are shown to comply by this option under the Envelope Component Method. If the Insulation R-value option is used, this space may be left blank. The PROPOSED value is taken either from an Energy Commission table of defaults, or is calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C - F and Sections 3.3.4 - 3.3.6). If a default table value is used, check the “Y” (yes) box. If a calculated value is used, check the “N” (no) box and attach the corresponding ENV-3 form. The ALLOWED value is taken from Tables 3-20 and 3-21.

D. Windows

1. **WINDOW NAME** - provide a name or designator for each unique type of window. This designator should be used consistently throughout the plan set (elevations, window schedules, etc.) to identify each window. It should also be consistently used on the other forms in the compliance documentation.

2. **ORIENTATION -** indicate orientation (see Section 3.1.2A for definitions) of each unique type of window. A window with an overhang and a similar window without an overhang would be different types. If overhangs are not used, similar windows on non-north orientations may be grouped together.

3. **U-VALUE** - PROPOSED glazing U-value is determined as discussed in Section 3.1.2H. ALLOWED U-value is taken from Tables 3-20 and 3-21.

4. **NO. OF PANES** - indicate “2” for double glazed, “1” for single glazed windows.

5. **PROPOSED RSHG** – indicate SHGC (Solar Heat Gain Coefficient), OHF (Overhang Factor), and the resulting RSHG (RSHG = SHGCwin x $[1 + aH/V + b(H/V)^2]$). See Sections 3.1.2I and J. If given window does not have an overhang, then SHGC and RSHG are the same.

6. **ALLOW. RSHG** - the Maximum Relative Solar Heat Gain allowed, taken from Tables 3-20 and 3-21, depending on the window orientation (north or non-north).

E. Skylights

1. **SKYLIGHT NAME** - provide a name or designator for each unique type of skylight. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each skylight. It should also be consistently used on the other forms in the compliance documentation.

2. **GLAZING** - Indicate if the glazing is transparent or translucent. This affects the allowed solar heat gain coefficient.

3. **NO. OF PANES** - indicate “2” for double glazed, “1” for single glazed skylights.

4. **U-VALUE** - PROPOSED glazing U-value is determined as discussed in Section 3.1.2H. ALLOWED U-value is taken from Tables 3-20 and 3-21.

5. **SOLAR HEAT GAIN COEFFICIENT** - indicate PROPOSED solar heat gain coefficient. See Section 3.1.2I. The ALLOWED value is the Maximum Solar Heat Gain Coefficient taken from Tables 3-20 and 3-21, depending on the type of glazing (transparent or translucent).

F. Sample Form: ENV-2 Envelope Component Method

ENVELOPE COMPONENT METHOD ENV-2

PROJECT NAME	DATE

WINDOW AREA CALCULATION SKYLIGHT AREA CALCULATION

GROSS WALL AREA (GWA)		DISPLAY PERI-METER (DP)	
GWA x 0.40		DP x 6	

GREATER OF

MAX. ALLOWABLE WINDOW AREA: ______

PROPOSED WINDOW AREA: ______

If the PROPOSED WINDOW AREA is greater than the MAXIMUM ALLOWABLE WINDOW AREA, go to another method.

ATRIUM HEIGHT ______ FT

IF $\le$ 55 FT | IF > 55 FT

		GROSS ROOF AREA		ALLOWED AREA
0.10	x		=	
0.05	x		=	

ACTUAL SKY. AREA: ______

If the ACTUAL SKYLIGHT AREA is greater than the ALLOWED SKYLIGHT AREA, go to another method.

OPAQUE SURFACES

ASSEMBLY NAME (eg. Wall-1, Floor-1)	TYPE (eg. Roof, Wall, Floor)	HEAT CAPACITY	INSULATION R-VALUE*		ASSEMBLY U-VALUE*			
			PROPOSED	MINIMUM ALLOWED	PROPOSED	TABLE VALUES? Y	N	MAXIMUM ALLOWED
						☐	☐	
						☐	☐	
						☐	☐	
						☐	☐	
						☐	☐	

* For each assembly type, meet the minimum insulation R-value or the maximum assembly U-value.

WINDOWS

WINDOW NAME (e.g., Window-1, Window-2)	ORIENTATION				U-VALUE		# OF PANES	PROPOSED RSHG						ALLOWED RSHG
	N	E	S	W	PROP.	ALLOW.		SHGC	H	V	H/V	OHF	PROP. RSHG	
	☐	☐	☐	☐										
	☐	☐	☐	☐										
	☐	☐	☐	☐										
	☐	☐	☐	☐										

SKYLIGHTS

SKYLIGHT NAME (e.g., Sky-1, Sky-2)	GLAZING		# OF PANES	U-VALUE		SOLAR HEAT GAIN COEFFICIENT	
	TRANSLUCENT	TRANSPARENT		PROPOSED	ALLOWED	PROPOSED	ALLOWED
	☐	☐					
	☐	☐					
	☐	☐					
	☐	☐					

3.3.3 ENV-2: Overall Envelope Method

This version of ENV-2 should be used only when the envelope is shown to comply using the Overall Envelope Method.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. ENV-2 Part 1 of 5

The first part of this form involves tests of glazing area for windows and skylights. If either of these tests does not pass, then the glazing area must be adjusted for the standard envelope.

Window Area Test

A. **DISPLAY PERIMETER** - refer to Section 3.1.2.A for definition and discussion. This is multiplied by 6 to determine the DISPLAY AREA for glazing limits.

B.-D. **GROSS EXTERIOR WALL AREA** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 0.4 to determine the 40% area for glazing limits, and by 0.1 to determine the minimum area for glazing limits. The larger of the DISPLAY AREA and the 40% AREA is the MAXIMUM AREA.

E. **PROPOSED WINDOW AREA** - the total area of proposed windows shown on the plans is entered here. See Section 3.1.2A for definition and discussion.

If it is necessary to proceed to the following calculations, then the window area will be adjusted for the standard envelope. Otherwise, the window calculations on Parts 2 through 4 can be done without adjusted window or wall areas. Proceed to the SKYLIGHT AREA TEST.

1. or 2. **WINDOW ADJUSTMENT FACTOR** - depending on the values of E, D and C, one of these two calculations is done to obtain the WINDOW ADJUSTMENT FACTOR. This number is carried to Part 5 of the form to calculate the adjusted window and wall areas. Upon completion of those calculations, Parts 2 through 4 may be completed.

Skylight Area Test

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the Standard Envelope.

1. **ATRIUM HEIGHT -** refer to Section 3.1.2.A for definition and discussion.

2. **STANDARD %** - depending on the atrium height, the allowed standard percentage of roof area for skylights may be 5% (0.05) or 10% (0.1).

3. **GROSS ROOF AREA** - gross roof area - refer to Section 3.1.2A for definition and discussion.

4. **STANDARD SKYLIGHT AREA** - the maximum allowed standard skylight area is the product of the previous two numbers.

5. **PROPOSED SKYLIGHT AREA** - the total area of proposed skylights shown on the plans is entered here. See Section 3.1.2A for definition and discussion.

If it is necessary to proceed to the following calculation, then the skylight area will be adjusted for the standard envelope. Otherwise, the skylight calculations on Part 2 and Part 3 can be done without the adjusted skylight or roof areas.

1. or 2. **SKYLIGHT ADJUSTMENT FACTOR** - this calculation is done to obtain the SKYLIGHT ADJUSTMENT FACTOR. This number is carried to Part 5 of the form to calculate the adjusted skylight and roof areas. Upon completion of those calculations, Parts 2 through 4 may be completed.

B. ENV-2 Part 2 of 5 Overall Heat Loss

This form should be used to confirm that the proposed envelope design has an overall heat loss no greater than the standard heat loss for the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. For windows and skylights, list the number of panes of glazing; indicate “2” for double glazed, “1” for single glazed windows.

B. **PROPOSED AREA** - enter the actual area, in square feet, of each assembly. Refer to Section 3.1.2.A for definitions and discussion.

C. **PROPOSED HEAT CAPACITY -** see Section 3.1.2.G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies but if it is blank then the lower U-value requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

D. **PROPOSED U-VALUE** - enter the U-value of the proposed assembly as designed. U-values are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C - F and Sections 3.3.4 - 3.3.6).

   TABLE VALUES? - if the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly type shown in Table B-7, e.g. R.30.2 x 10.16, in the "Roofs/Ceilings" and "Floors/Soffits" categories under the "Assembly Name" column of Form ENV-2 Part 2 "Overall Envelope Method". Enter the "Assembly Name" as instructed in the form, followed by the "Reference Name".

E. **PROPOSED UA** - the numbers in columns B and D are multiplied together and the result entered in this column.

F. **STANDARD AREA -** if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each assembly. If adjustments are required, then the adjusted areas of window, wall, skylight and roof are taken from Part 5.

G. **STANDARD U-VALUE** - enter the Maximum U-value for each assembly type, taken from Tables 3-20 and 3-21. The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

H. **STANDARD UA** - the numbers in columns F and G are multiplied together and the result entered in this column.

Columns E and H are totaled and the results compared. If the Column E total is no greater than the Column H total, then the Overall Heat Loss requirement has been met.

C. ENV-2 Part 3 of 5 Overall Heat Gain from Conduction

This form should be used to confirm that the proposed envelope design has an overall heat gain from opaque surfaces no greater than the standard heat gain for the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. For windows and skylights, list the number of panes of glazing; indicate "2" for double glazed, "1" for single glazed windows.

B. **PROPOSED AREA** - enter the actual area, in square feet, of each assembly. Refer to Section 3.1.2.A for definitions and discussion.

C. **TEMPERATURE FACTOR** - enter the temperature factor based on the envelope type and Climate Zone from Table 3-22 or *Standards* Table No. 1-J.

D. **PROPOSED HEAT CAPACITY -** see Section 3.1.2.G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies but if it is blank then the lower U-value requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

E. **PROPOSED U-VALUE** - enter the U-value of the proposed assembly as designed. U-values are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C - F and Sections 3.3.4 - 3.3.6), or from EZ-FRAME output.

   TABLE VALUES? - if the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly type shown in Table B-7, e.g. R.30.2 x 10.16, in the "Roofs/Ceilings" and "Floors/Soffits" categories under the "Assembly Name" column of Form ENV-2 Part 2 "Overall Envelope Method". Enter the "Assembly Name" as instructed in the form, followed by the "Reference Name".

F. **HEAT GAIN Q** - the numbers in columns B, C and E are multiplied together and the result entered in this column.

G. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 5.

H. **STANDARD U-VALUE** - enter the Maximum U-value for each assembly type, taken from Tables 3-20 and 3-21. The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

I. **TEMPERATURE FACTOR** - enter the temperature factor based on the envelope type and climate zone from Table 3-22 or *Standards* Table No. 1-J.

J. **HEAT GAIN Q** - the numbers in columns G, H and I are multiplied together and the result entered in this column.

Columns F and J are totaled and the results compared. If the Column F total is no greater than the Column J total, then the Overall Heat Gain requirement has been met.

D. ENV-2 Part 4 of 5 Overall Heat Gain from Radiation

This form should be used to confirm that the proposed envelope design has an overall heat gain no greater than the standard heat gain for the building.

A. **WINDOW/SKYLIGHT NAME** - provide a name or designator for each orientation of glazing under the appropriate heading (NORTH, SOUTH, SKYLIGHTS, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. **WEIGHTING FACTOR** - enter the weighting factor for each orientation and skylight. The weighting factors are taken from Table 3-23 or *Standards* Table No. 1-K, and depend on the climate zone (from ENV-1, Part 1).

C. **PROPOSED AREA** - the total area of proposed windows and skylights shown on the plans is entered here. See Section 3.1.2A for definitions and discussion.

D. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-22 or *Standards* Table No. 1-J.

E. **PROPOSED SHGC** - the proposed solar heat gain coefficient of the glazing. See Section 3.1.2I.

F.-H. **PROPOSED OVERHANG** - indicate the overhang horizontal length (H), the overhang vertical height (V); overhang ratio (H/V); and overhang factor (OHF). Column F includes both (H for horizontal) and (V for vertical). See Section 3.1.2J. The overhang adjustment does not apply to skylights.

I. **PROPOSED TOTAL** - multiply columns B, C, D, E & H and enter the result here.

J. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 5.

K. **STANDARD RSHG** - this is the Maximum Relative Solar Heat Gain taken from Tables 3-20 and 3-21 depending on the window orientation (north or non-north). The Maximum Solar Heat Gain Coefficient for skylights is taken from the same table, depending on whether the skylight glazing is transparent or translucent.

L. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-22 or *Standards* Table No. 1-J.

M. **STANDARD TOTAL -** multiply columns B, J, K & L and enter the result here.

Columns I and M are totaled, Totals from Columns F and J from Part 3 of 5 are carried forward and added, and the results compared. If the Column I total is no greater than the Column M total, then the Overall Heat Gain requirement has been met.

E. ENV-2 Part 5 of 5 Window Area Adjustment Calculations

This form should be included with all compliance submittals. If the WINDOW AREA TEST or the SKYLIGHT AREA TEST (Part 1 of this form) determines that area adjustments are not necessary, check the NOT APPLICABLE boxes. If the tests indicate that adjustments must be made, perform the calculations in the appropriate sections below.

A. **WALL NAME** - provide a name or designator for each unique type and orientation of wall that contains windows (walls without windows will have no adjustment). If an orientation has two different wall types, list each separately. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. See Section 3.1.2A for a discussion of orientation.

B.-D. **AREAS** - list the areas (in square feet). See Section 3.1.2.A for definitions of these areas. The GROSS AREA is the Gross Exterior Wall Area for the particular wall type and orientation under consideration. The DOOR AREA and WINDOW AREA are for doors and windows included in each wall.

E. **WINDOW ADJUSTMENT FACTOR** is calculated on the top half of Part 1. It is the same for all windows in the building.

F. **ADJUSTED WINDOW AREA** is calculated by multiplying the values in Columns D and E.

G. **ADJUSTED WALL AREA** is calculated by subtracting B from the sum of C and F. If this produces a negative value enter zero.

Add Columns B, C, D, F and G. As a check, the total of Column B should equal the sum of the totals of Columns F & G.

The total in Column G is used in Column F of the Overall Heat Loss calculation (Part 2) and Column I of the Overall Heat Gain from Conduction calculation (Part 3) and the values in Column F are used in Column G of the Overall Heat Gain from Radiation calculation (Part 4).

Skylight Area Adjustment Calculations

A. **ROOF NAME** - provide a name or designator for each unique type of roof that contains skylights (roofs without skylights will have no adjustment). If an orientation has two different roof types, list each separately. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B.-C. **AREAS** - list the areas (in square feet). See Section 3.1.2A for definitions of these areas. The GROSS AREA is the Gross Exterior Roof Area for the particular roof type and orientation under consideration; note that it does not include doors, such as roof hatches. The SKYLIGHT AREA is for skylights included in each roof.

D. **SKYLIGHT ADJUSTMENT FACTOR** is the Skylight Adjustment Factor calculated on the bottom half of Part 1. It is the same for all skylights in the building.

E. **ADJUSTED SKYLIGHT AREA** is calculated by multiplying the values in columns C and D.

F. **ADJUSTED ROOF AREA** is calculated by subtracting E from B. If this results in a negative value enter zero.

Columns B, C, E and F are added. As a check, the total of Column B should equal the sum of the totals of Columns E and F.

The totals in Columns E and F are used in Column F of the Overall Heat Loss calculation (Part 2) and in Column G of the Overall Heat Gain from Conduction calculation (Part 3), and the values in Column E are used in Column I of the Overall Heat Gain from Radiation calculation (Part 4).

F. Sample Form: ENV-2 Overall Envelope Method

OVERALL ENVELOPE METHOD (Part 1 of 5) ENV-2

PROJECT NAME	DATE

WINDOW AREA TEST

A. DISPLAY PERIMETER		FT × 6 =		SF DISPLAY AREA
B. GROSS EXTERIOR WALL AREA		SF × 0.40 =		SF 40% AREA
C. GROSS EXTERIOR WALL AREA		SF × 0.10 =		SF MINIMUM STANDARD AREA
D. ENTER LARGER OF A OR B				SF MAXIMUM STANDARD AREA
E. ENTER PROPOSED WINDOW AREA				SF PROPOSED AREA

IF E IS GREATER THAN D OR LESS THAN C, PROCEED TO THE NEXT CALCULATION FOR WINDOW AREA ADJUSTMENT. IF NOT, GO TO PART 2 OF 5.

1. IF E IS GREATER THAN D:

MAXIMUM STANDARD AREA ÷ PROPOSED WINDOW AREA = WINDOW ADJUSTMENT FACTOR

GO TO PART 5 TO CALCULATE ADJUSTED AREA

2. IF LESS THAN C:

MAXIMUM STANDARD AREA ÷ PROPOSED WINDOW AREA (IF E = 0 ENTER 1) = WINDOW ADJUSTMENT FACTOR

GO TO PART 5 TO CALCULATE ADJUSTED AREA

SKYLIGHT AREA TEST

ATRIUM HEIGHT ______ FT

OR

IF ≤ 55 FT → 0.05 x [GROSS ROOF AREA] = [STANDARD SKYLIGHT AREA]

IF > 55 FT → 0.10 x [GROSS ROOF AREA] = [STANDARD SKYLIGHT AREA]

STANDARD % | GROSS ROOF AREA | **STANDARD SKYLIGHT AREA**

PROPOSED SKYLIGHT AREA

IF THE PROPOSED SKYLIGHT AREA IS GREATER THAN THE STANDARD SKYLIGHT AREA, PROCEED TO THE NEXT CALCULATION FOR THE SKYLIGHT AREA ADJUSTMENT. IF NOT, GO TO PART 2 OF 5.

1. IF PROPOSED SKYLIGHT AREA ≥ STANDARD SKYLIGHT AREA:

STANDARD SKYLIGHT AREA ÷ PROPOSED SKYLIGHT AREA (IF E = 0 ENTER 1) = SKYLIGHT ADJUSTMENT FACTOR

GO TO PART 5 TO CALCULATE ADJUSTED AREAS

OVERALL ENVELOPE METHOD (Part 2 of 5) ENV-2

PROJECT NAME	DATE

OVERALL HEAT LOSS

	A			B	C	D	E			F	G	H
				PROPOSED						STANDARD		
	ASSEMBLY NAME (e.g. Wall-1, Floor-1)			AREA	HEAT CAPACITY	U-VALUE	TABLE VALUES? Y	N	UA (B × D)	AREA* (Adjusted)	U-VALUE	UA (F × G)
WALLS							☐	☐				
WALLS							☐	☐				
WALLS							☐	☐				
WALLS							☐	☐				
WALLS							☐	☐				
WALLS							☐	☐				
ROOFS/CEILINGS							☐	☐				
ROOFS/CEILINGS							☐	☐				
ROOFS/CEILINGS							☐	☐				
ROOFS/CEILINGS							☐	☐				
ROOFS/CEILINGS							☐	☐				
ROOFS/CEILINGS							☐	☐				
FLOORS/SOFFITS							☐	☐				
FLOORS/SOFFITS							☐	☐				
FLOORS/SOFFITS							☐	☐				
FLOORS/SOFFITS							☐	☐				
FLOORS/SOFFITS							☐	☐				
FLOORS/SOFFITS							☐	☐				
WINDOWS		# OF PANES			N/A		☐	☐				
WINDOWS		# OF PANES			N/A		☐	☐				
WINDOWS		# OF PANES			N/A		☐	☐				
WINDOWS		# OF PANES			N/A		☐	☐				
WINDOWS		# OF PANES			N/A		☐	☐				
WINDOWS		# OF PANES			N/A		☐	☐				
SKYLIGHTS		# OF PANES			N/A		☐	☐				
SKYLIGHTS		# OF PANES			N/A		☐	☐				
SKYLIGHTS		# OF PANES			N/A		☐	☐				
SKYLIGHTS		# OF PANES			N/A		☐	☐				
SKYLIGHTS		# OF PANES			N/A		☐	☐				
SKYLIGHTS		# OF PANES			N/A		☐	☐				

* If Window and/or Skylight Area Adjustment is Required, use adjusted areas from part 5 of 5.

TOTAL ◄ Column E shall be no greater than column H ► TOTAL

OVERALL ENVELOPE METHOD (Part 3 of 5) ENV-2

PROJECT NAME	DATE

OVERALL HEAT GAIN FROM CONDUCTION

	A		B	C	D	E			F	G	H	I	J
			PROPOSED							STANDARD			
	ASSEMBLY NAME (e.g. Wall-1, Floor-1)	# OF PANES	AREA	TEMP. FACTOR	HEAT CAPACITY	U-VALUE	TABLE VALUES? Y	TABLE VALUES? N	HEAT GAIN (B ×C ×E)	AREA* (Adjusted)	U-VALUE	TEMP. FACTOR	HEAT GAIN (G ×H ×I)
WALLS							☐	☐					
WALLS							☐	☐					
WALLS							☐	☐					
WALLS							☐	☐					
WALLS							☐	☐					
WALLS							☐	☐					
ROOFS/CEILINGS							☐	☐					
ROOFS/CEILINGS							☐	☐					
ROOFS/CEILINGS							☐	☐					
ROOFS/CEILINGS							☐	☐					
ROOFS/CEILINGS							☐	☐					
ROOFS/CEILINGS							☐	☐					
FLOORS/SOFFITS							☐	☐					
FLOORS/SOFFITS							☐	☐					
FLOORS/SOFFITS							☐	☐					
FLOORS/SOFFITS							☐	☐					
FLOORS/SOFFITS							☐	☐					
FLOORS/SOFFITS							☐	☐					
WINDOWS					N/A		☐	☐					
WINDOWS					N/A		☐	☐					
WINDOWS					N/A		☐	☐					
WINDOWS					N/A		☐	☐					
WINDOWS					N/A		☐	☐					
WINDOWS					N/A		☐	☐					
SKYLIGHTS					N/A		☐	☐					
SKYLIGHTS					N/A		☐	☐					
SKYLIGHTS					N/A		☐	☐					
SKYLIGHTS					N/A		☐	☐					
SKYLIGHTS					N/A		☐	☐					
SKYLIGHTS					N/A		☐	☐					
									SUBTOTAL				SUBTOTAL

* If Window and/or Skylight Area Adjustment is Required, use adjusted areas from part 5 of 5.

OVERALL ENVELOPE METHOD (Part 4 of 5) ENV-2

PROJECT NAME	DATE

OVERALL HEAT GAIN FROM RADIATION

	A	B	C	D	E	F		G	H	I	J	K	L	M
			PROPOSED								STANDARD			
	WINDOW/SKYLIGHT NAME (e.g Window-1, Sky-1)	WEIGHTING FACTOR	AREA	SOLAR FACTOR	SHGC	OVERHANG H	OVERHANG V	OVERHANG H/V	OVERHANG OHF	HEAT GAIN (BxCx DxExH)	AREA (Adjusted)*	RSHG or SHGC**	SOLAR FACTOR	HEAT GAIN (B×J×K×L)
NORTH														
EAST														
SOUTH														
WEST														
SKYLIGHTS						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					

Proposed		Standard	
Part 4 Subtotal		Part 4 Subtotal	
Part 3 Subtotal		Part 3 Subtotal	
TOTAL		TOTAL	

* If Window and/or Skylight Area Adjustment is Required, use adjusted areas from part 5 of 5.

** Only SHGC is used for Skylights

Column **I** must be less than column **M**

OVERALL ENVELOPE METHOD (Part 5 of 5) ENV-2

PROJECT NAME	DATE

WINDOW AREA ADJUSTMENT CALCULATIONS

☐ CHECK IF NOT APPLICABLE (see Part 1 of 5)

A					B	C	D	E	F	G
WALL NAME (e.g. Wall-1, Wall-2)	ORIENTATION				GROSS AREA	DOOR AREA	WINDOW AREA	WINDOW ADJUSTMENT FACTOR (From Part 1)	ADJUSTED WINDOW AREA (D×E)	ADJUSTED WALL AREA B-(F+C)
	N	E	S	W						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
TOTALS:										

SKYLIGHT AREA ADJUSTMENT CALCULATIONS

☐ CHECK IF NOT APPLICABLE (see Part 1 of 5)

A	B	C	D	E	F
ROOF NAME (e.g. Roof-1, Roof-2)	GROSS AREA	SKYLIGHT AREA	SKYLIGHT ADJUSTMENT FACTOR (From Part 1)	ADJUSTED SKYLIGHT AREA (C×D)	ADJUSTED ROOF AREA (B - E)
TOTALS:					

3.3.4 ENV-3: Proposed Metal Framed Assembly

For most metal framed assemblies, the U-value will be found in Table B-2 in Appendix B (see Section 3.1.2E for a discussion of the use of this table). When there is no appropriate U-value in Table B-2, then this version of ENV-3 should be used to calculate the assembly U-value.

[Note that this form is not used to describe metal furring systems for insulating masonry or concrete walls; these are described in ENV-3 Masonry Assemblies.]

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of framing members and layers should be apparent. Number the layers in sequence from outside to inside as they will be described below (framing members are not numbered, only the cavity layers are considered here). Note that the outside of the assembly, facing unconditioned space, is at the left.
2. **ASSEMBLY NAME** - list the name or designator for this assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, ROOF-2, or some other naming convention appropriate to the construction document organization.
3. **ASSEMBLY TYPE** - check the appropriate box.
4. **FRAMING MATERIAL** - must be metal for this form (other versions of ENV-3 are for other framing materials).
5. **FRAMING SIZE** - enter the nominal dimensions of the framing members, e.g. 3 1/2", 5 1/2", or other appropriate description.
6. **INSULATION R-VALUE** - enter the R-value of the insulation material in the assembly. If there is more than one insulation material, list each separately.

B. Construction Components

In this part of the form, the R-value of the cavity (the area of the wall that does not contain framing members) is calculated.

1. **DESCRIPTION** - list each layer of the assembly in sequence, from outside to inside, as numbered in the sketch above.

2. **CAVITY R-VALUE (R_c) -** enter the R-value of each layer. This value is taken from manufacturers' literature or from the *ASHRAE Handbook of Fundamentals Volume, 1993,* Chapter 22, Table 4, *Typical Thermal Properties of Common Building and Insulating Materials.* The R-values for the INSIDE and OUTSIDE SURFACE AIR FILMS are taken from Table 3-1, Standard Air Film R-values.

3. **METAL FRAMING FACTOR (MFF)** - enter the appropriate value for the assembly from Table 3-5 (Appendix B, Table B-3), or the table on the form.

4. **Rc X MFF** - multiply the SUBTOTAL R-value (R_c) for the cavity by the METAL FRAMING FACTOR and enter the result.

5. **INSULATING SHEATHING -** if there is a layer of insulating sheathing (other than the cavity insulation between the framing members), enter its R-value. Only values from *ASHRAE Handbook of Fundamentals Volume, 1993,* Table 3a, Chapter 23, may be used.

6. **TOTAL R-VALUE (R_t)** - add the previous two numbers and enter the result here.

7. **ASSEMBLY U-VALUE** - divide 1 by the TOTAL R-VALUE (R_t) to obtain the ASSEMBLY U-VALUE.

COMMENTS may be added to further explain the assembly or its U-value calculation. This would be especially helpful for unusual assemblies, and could help to expedite plan checking for energy compliance.

C. Sample Form: ENV-3 Proposed Metal Framed Assembly

PROPOSED METAL FRAMED ASSEMBLY ENV-3

PROJECT NAME	DATE

COMPONENT DESCRIPTION

OUTSIDE

INSIDE

SKETCH OF ASSEMBLY

ASSEMBLY NAME		
ASSEMBLY TYPE		Floor
		Wall
		Ceiling/Roof
FRAMING MATERIAL		
FRAMING SIZE		
FRAMING SPACING	16” o. c. ☐	24” o. c. ☐
INSULATION R-VALUE		

CONSTRUCTION COMPONENTS

	DESCRIPTION	CAVITY R-VALUE (Rc)
	OUTSIDE SURFACE AIR FILM	
1		
2		
3		
4		
5		
6		
7		
	INSIDE SURFACE AIR FILM	

METAL FRAMING FACTOR			
Stud Spacing	Stud Depth	Insulation R-Value	Non-Mass Wall
16 o. c.	4”	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6”	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24 o. c.	4”	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6”	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308

SUBTOTAL		Rt
METAL FRAMING FACTOR		MFF
Rt × MFF		R-VALUE
INSULATING SHEATHING		R-VALUE
TOTAL R-VALUE		Rt
1/Rt		ASSEMBLY U-VALUE

COMMENTS

3.3.5 ENV-3: Proposed Masonry Wall Assembly

This version of ENV-3 should be used for masonry wall assemblies (including concrete block, brick and solid concrete). It is used in conjunction with Tables B-4 and B-5 in Appendix B, which give U-values and heat capacities for most common assemblies. It should also be used to account for the insulating qualities of insulating sheathing and/or furred sheathing layers attached to the masonry. Refer to Section 3.1.2F for further description of these calculations.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and as known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of any furring members and sheathing layers should be apparent. Note that the outside of the assembly, facing unconditioned space, is at the left.

2. **WALL ASSEMBLY NAME** - list the name or designator for this wall assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, or some other naming convention appropriate to the construction document organization.

3. **DESCRIPTION OF ASSEMBLY** - provide a brief description of the materials used in the assembly to augment the sketch.

B. Wall R-value and Heat Capacity

This section is used to extract values of wall R-value and heat capacity from Tables B-4 or B-5 in Appendix B.

1. **WALL UNIT THICKNESS** - enter the nominal thickness, in inches, of the masonry wall.

2. **MATERIAL TYPE** - enter the material type. For concrete block, this can be “light weight”, “medium weight”, or “normal weight” as per ASTM designations.

3. **CORE TREATMENT** - this is only applicable to hollow core masonry units; the choices are solid grouted cores, or partially grouted cores with the unfilled cells either empty or filled with any type of insulation.

4. **WALL R-VALUE (R_w)** - for hollow masonry, use Table B-4; for solid unit masonry or solid concrete walls, use Table B-5. Select the appropriate R-value and enter it here (see Section 3.1.2F for more discussion).

5. **WALL HEAT CAPACITY (HC)** - for hollow masonry, use Table B-5; for solid unit masonry or solid concrete walls, use Table B-5. Select the appropriate HC value and enter it here (see Section 3.1.2G for more discussion).

C. Furring/Insulation Layer

This section is used to describe any furring/insulation layers or insulating sheathing attached to either the inside or the outside of the masonry.

1. **FURRING FRAMING MATERIAL** - list the type of material (wood, metal) used for the furring strips; if not applicable enter "none".

2. **FURRING FRAMING SIZE** - enter the thickness, width, and depth, in actual inches, of the framing members used for furring, and its actual dimensions in inches.

3. **FURRING SPACE INSULATION** - enter the type of insulation installed in the space between furring strips (fiberglass batt, bead board, etc.), and its R-value at the installed thickness.

4. **EXTERIOR INSULATING LAYER** - if there is an exterior insulating layer, list the type of insulation (bead board, polyisocyanurate board, etc.), and its R-value at the installed thickness.

5. **FURRING ASSEMBLY EFFECTIVE R-VALUE** - using the information above, enter Table B-6 and locate the effective R-value of the furring assembly (see Section 3.1.2F).

6. **INSULATION LAYER R-VALUE (R_f)** - add the FURRING ASSEMBLY EFFECTIVE R-VALUE to the R-value of the exterior insulating layer to arrive at the INSULATION LAYER R-VALUE (R_f).

D. Wall Assembly R-value and U-value

1. **WALL ASSEMBLY R-VALUE (R_t)** - add the INSULATION LAYER R-VALUE calculated above (R_t) to the WALL R-VALUE (R_w) from above to obtain the WALL ASSEMBLY R-VALUE.

2. **WALL ASSEMBLY U-VALUE** - calculate the inverse of the WALL ASSEMBLY R-VALUE ($1/R_t$) to obtain the WALL ASSEMBLY U-VALUE.

E. Sample Form: ENV-3 Proposed Masonry Wall Assembly

PROPOSED MASONRY WALL ASSEMBLY — ENV-3

PROJECT NAME	DATE

COMPONENT DESCRIPTION

OUTSIDE | INSIDE

SKETCH OF ASSEMBLY

ASSEMBLY NAME

DESCRIPTION OF ASSEMBLY

WALL R-VALUE and HEAT CAPACITY

WALL UNIT THICKNESS		NOMINAL INCHES
MATERIAL TYPE		(LW CMU,MW CMU, NW CMU, CLAY UNIT, CLAY BRICK, CONCRETE.)
CORE TREATMENT		(SOLID, GROUTED, EMPTY, INSULATED, NA)
WALL R-VALUE		Rw (FROM TABLE B-4 or B-5)
WALL HEAT CAPACITY		HC (FROM TABLE B-4 or B-5)

FURRING/INSULATION LAYER (INSIDE and/or OUTSIDE IF ANY)

FURRING FRAMING MATERIAL		(WOOD, METAL, NONE)		
FURRING FRAMING SIZE		NOMINAL INCHES		ACTUAL INCHES
FURRING SPACE INSULATION		TYPE		R-VALUE
EXTERIOR INSULATING AREA		TYPE		R-VALUE

FURRING ASSEMBLY EFFECTIVE R-VALUE		**EXTERIOR INSULATING LAYER R-VALUE**		**INSULATION LAYER R-VALUE**
	+		=	Rf
(FROM TABLE B-7)		(FROM MANUFACTURER)		

WALL ASSEMBLY R-VALUE and U-VALUE

INSULATION LAYER R-VALUE		**WALL R-VALUE**		**WALL ASSEMBLY R-VALUE**		**WALL ASSEMBLY U-VALUE**
	+		=		➜	
Rf		**Rw**		**Rt**		**1/Rt**

3.3.6 ENV-3: Proposed Wood Frame Assembly

This version of ENV-3 should be used for any construction assembly that is not found in the tables in Appendix B or appropriate for the metal framed or masonry versions of ENV-3. This form guides the user through the basic U-value calculation, the Parallel Path Method (discussed in Section 3.1.2D), and the heat capacity calculation (see Section 3.1.2G). If the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, the "Reference Name" for the appropriate assembly is entered into either Form ENV-2 "Envelope Component Method" or ENV-2 Part 2 "Overall Envelope Method", whichever is applicable for the compliance method that the designer has selected. Refer to the specific sections in the Manual which provide instructions for filling out the respective forms, as to how the Reference Name of the assembly should be entered.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and as known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of framing members and layers should be apparent. Number the layers in sequence from outside to inside as they will be described below (framing members are not numbered, only the cavity layers are considered here). Note the outside of the assembly, facing unconditioned space, is at the left of the sketch.

2. **ASSEMBLY NAME** - list the name or designator for this assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, ROOF-2, or some other naming convention appropriate to the construction document organization.

3. **ASSEMBLY TYPE** - check the appropriate box.

4. **FRAMING MATERIAL** - with this form framing material is wood only (other versions of ENV-3 are for other materials).

5. **FRAMING SIZE** - enter the nominal dimensions of the framing members, e.g. 2x4, 4x8, or other appropriate description.

6. **FRAMING PERCENTAGE** - choose the appropriate value from the small table to the right. For example, a floor assembly with joists spaced 24" on center (o.c.) would have a framing percentage of 7%.

B. Construction Components

In this part of the form, the R-value of the cavity (the area of the assembly that does not contain framing members) and the R-value of the assembly through the wood framing are calculated. The U-value of the assembly is also calculated.

1. **DESCRIPTION** - list each layer of the assembly in sequence, from outside to inside, as numbered in the sketch above.

2. **CAVITY R-VALUE (R_c) -** enter the R-value of each layer at a cross-section taken through the cavity. This value is taken from manufacturer's literature or from *the ASHRAE Handbook of Fundamentals Volume, 1993,*

(Chapter 22, Table 4, *Typical Thermal Properties of Common Building and Insulating Materials*) data reproduced in Appendix B, Table B-1. The R-values for the INSIDE and OUTSIDE SURFACE AIR FILMS are taken from Table 3-1, Standard Air Film R-values.

3. **WOOD FRAME R-VALUE (R_f)** - enter the R-value of each layer at a cross-section taken through a framing member. These values are found in the same sources cited in the previous paragraph.

4. **HEAT CAPACITY (HC) -** As an option, the HC of the assembly may also be calculated, although for most framed assemblies the HC will be too low to be of significance (HC values of less than 7 are not given any special consideration under the *Standards*).

5. **WALL WEIGHT -** enter the weight of each layer of the assembly, per square foot of the material at its given thickness. This is calculated from the density of the material, which is given in pounds per cubic foot. See Table 3-9 for typical values; they may also be taken from manufacturers literature or other standard reference works, such as the *ASHRAE Handbook of Fundamentals Volume, 1993*, Chapter 22 Table 4 (Appendix B). Dividing the density by 12 and multiplying by the material thickness (in inches) yields the WALL WEIGHT. For the framing material, the weight of the framing members must be converted to a pounds per square foot value.

6. **SPECIFIC HEAT** - enter the specific heat of each material, in Btu/°F-lb. These values are also found in ASHRAE Table 4 (see previous paragraph).

7. **HC** - columns A and B are multiplied together to obtain the heat capacity for each layer of the assembly.

8. **SUBTOTALS** - both R-value columns are summed. If calculated, the HC column is also summed to obtain the TOTAL HC for the assembly.

9. **ASSEMBLY U-VALUE** - the appropriate values from above on this form are entered into the equation and the result calculated. Rc is the subtotal of the CAVITY R-VALUE column; R_f is the subtotal of the WOOD FRAME R-VALUE column. Fr% is the FRAMING PERCENTAGE. Care should be taken to recognize the parentheses in the calculation.

C. Sample Form: ENV-3 Wood Frame Assembly

PROPOSED WOOD FRAME ASSEMBLY — ENV-3

PROJECT NAME	DATE

COMPONENT DESCRIPTION

OUTSIDE — INSIDE

SKETCH OF ASSEMBLY

ASSEMBLY NAME ____

ASSEMBLY TYPE (check one)
- ☐ **Floor**
- ☐ **Wall**
- ☐ **Ceiling/Roof**

FRAMING MATERIAL ____

FRAMING SIZE ____ Fr %: ____

FRAMING PERCENTAGE ____
15% (16" o. c. Wall
12% (24" o. c. Wall)
10% (16" o. c. Floor/Ceil.)
7% (24" o. c. Floor/Ceil.)

CONSTRUCTION COMPONENTS

	DESCRIPTION	R-VALUE: CAVITY R-VALUE (Rc)	R-VALUE: WOOD FRAME R-VALUE	HEAT CAPACITY (optional): A WALL WEIGHT lbs/sf	HEAT CAPACITY (optional): B SPECIFIC HEAT (Btu/F°•lbs)	HEAT CAPACITY (optional): HC (A×B) (Btu/F°•sf)
	OUTSIDE SURFACE AIR FILM					
1						
2						
3						
4						
5						
6						
7						
	INSIDE SURFACE AIR FILM					
	SUBTOTAL	Rc	Rf		TOTAL HC	

[____ x ____] + [____ x ____] = ____

1/Rc — 1 - (Fr%/100) — 1/Rf — Fr%/100 — ASSEMBLY U-VALUE

COMMENTS

3.4 ENVELOPE INSPECTION

The envelope building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the ENV-1 Certificate of Compliance, or a similar form, that must be printed on the plans (see Section 3.3.1). Included on the ENV-1 are "Notes to Field" which are provided by the plan checker to alert the inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I.

Chapter 3 Index

A

Actual Skylight Area · 39
ADJUSTED ROOF AREA · 47
ADJUSTED SKYLIGHT AREA · 47
ADJUSTED WALL AREA · 47
ADJUSTED WINDOW AREA · 47
Agricultural · 32, 33
AIR FILMS · 8, 53, 60
Air Infiltration · 15
ALLOWED % · 39
Allowed Skylight Area · 39
Allowed U-value · 25
Alterations · 1, 30
Area · 24, 30
ASHRAE Handbook · 8, 9, 10, 53, 59, 60
Assembly · 1, 7, 8, 9, 10, 31, 39, 40, 44, 45, 53, 59, 60
ASSEMBLY NAME · 39, 44, 45, 53, 59
ASSEMBLY TYPE · 53, 59
ASSEMBLY U-VALUE · 40, 53, 57, 60
Atrium · 3

B

Building · 1, 17, 21, 22, 24, 25, 28, 53, 60
Building Envelope · 1, 22
Business and Professions Code · 32

C

California Code of Regulations · 31, 32
California Quality Standards for Insulating Material · 7, 16, 34
CAVITY R-VALUE · 53, 59, 60
Ceilings · 1, 17, 44, 45
Certificate of Compliance · 31, 32, 36, 62
Certified Insulating Materials · 16
Certified Products Directory · 12, 15
Climate · 23, 27, 31, 45
Climate Zone · 23, 31, 45
Compliance · 1, 17, 34
Component Description · 53, 56, 59
Components · 1
Concrete · 10, 11, 23
Conduction · 44, 47
Construction Components · 53, 59
Convention · 17

D

DATE OF PLANS · 31
Default Fenestration · 12, 15
Default Solar Heat Gain Coefficient · 13
Demising Partition · 3
Demising Wall · 1, 3, 16, 18, 34
Demising Wall Insulation · 34
Department of Consumer Affairs Consumer Guide · 16
DESCRIPTION OF ASSEMBLY · 56
Dimensions · 13
DISPLAY AREA · 43
Display Perimeter · 3
Documentation Author · 32
DOOR AREA · 47
Doors · 1, 12, 15, 34

E

East · 5, 14
Energy Calculations and Data · 10
Energy Use Goal · 30
ENV-1 · 1, 31, 34, 36, 39, 40, 43, 46, 56, 59, 62
ENV-2 · 1, 17, 22, 24, 26, 28, 30, 31, 39, 41, 43, 44, 45, 46, 47, 59
ENV-3 · 1, 8, 9, 10, 11, 31, 35, 40, 44, 45, 53, 54, 56, 57, 59, 60
Envelope Compliance · 1, 2
Envelope Component Approach · 2, 17, 19, 21, 22, 25, 44, 45
Envelope Concepts · 1, 3
Envelope Mandatory Measures · 34
Envelope Plan Check Documents · 1
Exterior Door · 1, 3, 5, 22
Exterior Floors and Soffits · 19
Exterior Joints · 34
Exterior Partition · 4
Exterior Roof/Ceiling · 4, 6
Exterior Shade · 35
Exterior Walls · 1, 18

F

Fenestration U-value · 1, 12
Field-Fabricated · 5
Floor/Soffit · 3, 4, 5, 20
Floors · 1, 44, 45
Framed Assemblies · 9
Framed Floor · 39, 44, 45, 59

Furring · 56

G

Garages · 32, 33
Garden Window · 12
General Commercial · 17
Glazing · 3, 4, 7, 13, 17, 20, 22, 25, 28, 29
Glazing Area · 25
Glazing Heat Transfer · 29
Glazing Orientation · 28
GLAZING TYPE · 35
GROSS AREA · 47
Gross Exterior Roof Area · 5, 47
Gross Exterior Wall Area · 5, 47
GROSS WALL AREA · 39
Guest Room · 23

H

Heat Capacity · 1, 11, 18, 19, 27, 56
Heat Gain · 1, 14, 19, 23, 28, 47
Heat Loss · 24, 25
Heat Transfer · 29
High-Rise Residential · 23
Hollow Unit Masonry · 10
Hotel/Motel · 23

I

Indirectly Conditioned Space · 4
Industrial · 17
Inspection · 1, 62
Insulating Material · 34, 53, 60
Insulation · 1, 7, 11, 16, 40, 56
INSULATION R-VALUE · 40, 53
Interzone Surfaces · 29

J

Joints · 1, 16

M

Malls · 3
Mandatory Measures · 1, 15, 34
Manufactured Doors · 34
Manufacturers · 16
Masonry · 1, 10, 11, 18, 31, 53, 56, 57
Masonry Assembly · 31
Masonry U-values · 1, 10
Masonry Wall Assembly · 10, 56, 57
Mass Wall · 11
Maximum Allowable Window Area · 39
Maximum Allowed Skylight Area · 39
Maximum Area · 19, 21
Maximum U-value · 19, 21, 44, 45
Medical · 17
Medium Mass · 27
Metal Frame U-values · 1, 9
Metal Framed Assembly · 9, 54
Metal Framing · 10
METAL FRAMING FACTOR · 53
METHOD OF COMPLIANCE · 32
Modeling · 1, 29
Modeling Envelope Components · 29

N

National Fenestration Rating Council · 12
Non-North · 23
North · 5, 23
Notes to Field · 36, 62

O

Opaque · 22, 29, 34, 39, 40
Opaque Surface · 29, 34, 39, 40
Openings · 1, 16
Orientation · 5
Overall Assembly U-value · 1, 7
Overall Envelope Approach · 2, 22, 24
Overall Heat Gain · 1, 26, 44, 45, 46, 47
Overall Heat Loss · 1, 24, 44, 47
Overhang · 13, 14, 35, 40
Overhang Factor · 14, 40

P

Parallel Path Method · 8, 59
Partition · 7, 9
Performance Approach · 1, 2, 17, 29
PHASE OF CONSTRUCTION · 32
Prescriptive Approach · 1, 2
Prescriptive Envelope · 17
Prescriptive Envelope Component Approach · 17
Prescriptive Overall Envelope Approach · 22
PRINCIPAL DESIGNER - ENVELOPE · 31
PROPOSED AREA · 44, 45, 46
Proposed Building Heat Gain · 26, 28
Proposed Building Heat Loss · 24, 26

Proposed Construction Assembly · 11, 31, 40, 44, 45, 59
PROPOSED OVERHANG · 46
PROPOSED RSHG · 40
PROPOSED SKYLIGHT AREA · 43
PROPOSED UA · 44
PROPOSED WINDOW AREA · 39, 43

R

Retail · 17
Roofs · 1, 17, 44, 45
RSHG · 14, 15, 20, 21, 23, 26, 27, 28, 40, 46
R-value · 1, 3, 7, 8, 9, 10, 16, 17, 18, 19, 22, 23, 40, 53, 56, 57, 59, 60

S

Sample Notes Block · 34
Schools · 17
Scope and Application · 1
SHGC · 2, 6, 12, 13, 14, 15, 20, 21, 22, 23, 26, 27, 28, 35, 40, 46
Skylight · 6, 12, 21, 22, 39, 43, 47
Skylight Adjustment Factor · 47
Skylight Area · 6, 39, 43, 47
SKYLIGHT NAME · 40
Slope · 6
Soffits · 1, 44, 45
Solar Heat Gain · 1, 6, 13, 20, 21, 23, 40, 41, 46
Solar Heat Gain Coefficient · 1, 6, 13, 21, 23, 40, 41, 46
South · 5
STANDARD AREA · 44, 45, 46
Standard Building · 24, 25, 26, 27, 28
Standard Building Heat Gain · 26, 27, 28
Standard Building Heat Loss · 24, 25, 26, 27
STANDARD SKYLIGHT AREA · 43
STANDARD UA · 44
STANDARD U-VALUE · 44, 45
Statement of Compliance · 32

T

Theaters · 17
Thermal Mass · 11
Thermal Resistance · 7
TOTAL R-VALUE · 53
Transparent · 23

U

UBC · 3, 21, 34
U-value · 3, 5, 6, 7, 8, 9, 10, 11, 12, 15, 17, 18, 19, 20, 21, 22, 23, 25, 26, 29, 31, 34, 35, 40, 44, 45, 53, 54, 57, 59

W

Wall · 1, 4, 6, 8, 9, 18, 19, 23, 56, 57
Wall Area · 4
Wall Assembly · 9, 57
WALL ASSEMBLY NAME · 56
WALL ASSEMBLY R-VALUE · 57
WALL ASSEMBLY U-VALUE · 57
WALL HEAT CAPACITY · 56
WALL NAME · 46
WALL R-VALUE · 56, 57
WALL UNIT THICKNESS · 56
Weighting factors · 28
Weighting Factors · 28
Well Index · 6
West · 5
Wholesale · 17
Window Area · 3, 6, 39, 43, 46
Window Area Adjustment Calculations · 46
Window Area Calculation · 39
Window Area Test · 43
WINDOW NAME · 40
Window Wall Ratio · 7
WINDOW/SKYLIGHT NAME · 46
Windows · 1, 12, 15, 19, 23, 34, 40
Wood Framing · 9

Chapter 4:

Mechanical Systems

4.0 CHAPTER OVERVIEW

This chapter summarizes the requirements for space-conditioning, ventilating and service water-heating systems. Section 4.1 introduces the approaches and concepts of mechanical system compliance with the Energy Efficiency Standards (*Standards*). The Mechanical Design Procedures, section 4.2, covers the mandatory, prescriptive and performance requirements for mechanical systems. For the convenience of designers, a summary of the most important requirements for many of the major heating, ventilating and air

Chapter Contents

4.1 Introduction 4-2
4.1.1. Mechanical Compliance Approaches 4-2
4.1.2. Basic Mechanical Concepts 4-3
A. Definitions of Efficiency 4-3
B. Definitions of Spaces and Systems 4-4
C. Types of Air 4-5
D. Air Deliver System 4-6
E. Attics and Return Plenums 4-6
F. Zone Reheat, Recool and Air Mixing 4-6
G. Economizers 4-7
H. Unusual Sources of Contaminants 4-8
I. Demand Control Ventilation 4-8
J. Intermittently Occupied Spaces 4-8
4.2 Mechanical Design Procedures 4-9
4.2.1 Mandatory Measures 4-9
A. Equipment Certification 4-9
B. Control Equipment Certification 4-10
C. Pilot Lights 4-10
D. Outdoor Ventilation 4-10
E. Natural Ventilation 4-11
F. Mechanical Ventilation 4-12
G. Ventilation System Operation and Controls 4-16
H. Required Controls for Space Conditioning Systems 4-21
I. Requirements for Pipe Insulation 4-26
J. Requirements for Ducts and Plenums 4-28
K. Service Water Systems 4-29
L. Pool/Spa Heating Systems 4-31
4.2.2 Prescriptive Approach 4-31
A. Sizing/Equipment Selection 4-31
B. Load Calculations 4-32
C. Fan Power Consumption 4-34
D. Space-conditioning Zone Controls 4-37
E. VAV Zone Controls 4-38
F. Economizers 4-38
G. Supply-Air Temperature Reset Control 4-40
H. Electric Resistance Heating 4-41
I. Service Water Heating 4-41
4.2.3 Performance Approach 4-41
A. Compliance with a Computer Method 4-42
B. Modeling Mechanical System Components 4-42
4.2.4 Alterations/Additions 4-42
4.2.5 Application to Major Systems Types 4-42
4.3 Mechanical Plan Check Documents 4-57
4.3.1 MECH-1: Certificate of Compliance 4-57
4.3.2 MECH-2: Mechanical Equipment Summary 4-69
4.3.3 MECH-3: Mechanical Ventilation 4-75
4.3.4 MECH-4: Mechanical Sizing and Fan Power 4-78
4.4 Mechanical Inspection 4-82

conditioning (HVAC) systems types is included at the end of this section. The Mechanical Plan Check, section 4.3, describes the information that must be included in the building plans and specifications to show compliance with the Standards including a presentation and discussion of the mechanical compliance forms. The Mechanical Inspection, section 4.4, refers to the Inspection Checklist in Appendix I identifying the items that the inspector will verify in the field.

4.1 INTRODUCTION

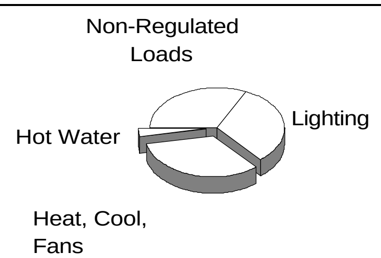


Figure 4-1: Typical Building Energy Use (Energy Efficiency Report, October, 1990, California Energy Commission Publication No. 400-90-003)

Mechanical systems are the second largest consumer of energy in most buildings, exceeded only by lighting. The proportion of space-conditioning energy consumed by various mechanical components varies according to system design and climate. For most buildings in nonmountainous California climates, fans or cooling equipment may be the largest consumer of energy. Space-heating energy is usually less than fans and cooling, followed by service water heating.

The objective of the *Standards* requirements for mechanical systems is to reduce energy consumption while maintaining occupant comfort. These goals are achieved by:

1. Maximizing equipment efficiency, both at design conditions as well as during part load operation

2. Minimizing distribution losses of heating and cooling energy

3. Optimizing system control to minimize unnecessary operation and simultaneous usage of heating and cooling energy

The *Standards* also recognize the importance of indoor air quality for occupant comfort and health. To this end, the *Standards* incorporate requirements for outdoor air ventilation which must be maintained during all operating conditions.

4.1.1. Mechanical Compliance Approaches

After the mandatory measures are met, the *Standards* allow mechanical system compliance to be demonstrated through prescriptive or performance requirements.

Mandatory measures (Sections 110-119 and 120-129) apply to all systems, whether the designer chooses the prescriptive or performance approach to compliance. Mandatory measures include:

1. Certification of equipment efficiency

2. Ventilation requirements

3. Thermostats, shut-off control and night setback/setup

4. Area isolation

5. Duct work construction and insulation

6. Pipe insulation

7. Service water heating and pool heating

Prescriptive measures cover items that can be used to qualify components and systems on an individual basis and are contained in Section 144. Prescriptive measures provide the basis for the *Standards* and are the prescribed set of measures to be installed in a building for the simplest approach to compliance. Prescriptive measures include:

1. Load calculations, sizing, system type and equipment selection Section 144(a) and (b))

2. Fan power consumption (Section 144(c))

3. Controls to reduce reheating, recooling and mixing of conditioned air streams; supply air reset; and variable air volume (VAV) box minimum position (Section 144(d) and (f))

4. Economizers (Section 144(e))

5. Restrictions on electric-resistance heating (Section 144(g))

The **Performance** approach (Section 141) allows the designer to increase the efficiency or effectiveness of selected mandatory and prescriptive measures, and to decrease the efficiency of other prescriptive measures. The performance approach requires the use of an Energy Commission certified computer program, and may only be used to model the performance of mechanical systems that are covered under the building permit application. (See Sections 2.2 and 6.1 for more detail.)

4.1.2. Basic Mechanical Concepts

This section presents definitions and key concepts that apply to mechanical systems. Definitions in italics are quoted from Section 101(b). Other definitions and concepts are not officially part of the *Standards*, but are included here as an aid in understanding the sections that follow.

A. Definitions of Efficiency

Section 111-112 mandate minimum efficiency requirements which regulated appliances and other equipment must meet. These efficiency requirements are listed in Table B-9 in Appendix B. The following describes the various measurements of efficiency used in the *Standards.*

The purpose of space-conditioning and water-heating equipment is to convert energy from one form to another, and to regulate the flow of that energy. Efficiency is a measure of how effectively the energy is converted or regulated. It is expressed as the ratio:

$$Efficiency = \frac{Output}{Input}$$

The units of measure in which the input and output energy are expressed may be either the same or different, and vary according to the type of equipment. The *Standards* use several different measures of efficiency.

Annual Fuel Utilization Efficiency (AFUE) *is a measure of the percentage of heat from the combustion of gas or oil which is transferred to the space being heated during a year, as determined using the applicable test method in the Appliance Efficiency Regulations or Section112, Table 1-C.* The AFUE is usually lower than thermal efficiency because it takes into account the effects of equipment cycling or modulation at loads than design. It is calculated using a prescribed annual load profile.

Coefficient of Performance (COP)**, Cooling**, *is the ratio of the rate of net heat removal to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units, as determined using the applicable test method in the Appliance Efficiency Regulations or Section112*.

$$COP = \frac{(Cooling\ Output\ Btu / hr)}{(Electric\ Input\ Btu / hr)}$$

As electricity is normally measured in Watts, electric input must be converted to Btu/hr.

Coefficient of Performance (COP)**, Heating**, *is the ratio of the rate of net heat output to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units, as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112.*

$$COP = \frac{(Heating\ Output\ Btu / hr)}{(Electric\ Input\ Btu / hr)}$$

Combustion Efficiency is not defined in the *Standards*, but is used as the efficiency measurement for large boilers and service water heaters. It is a measure of the percent of energy transfer from the fuel to the heat exchanger (HX). Input and output energy are expressed in the same units so that the result has nondimensional units:

$$\%\ Combustion\ Eff = \frac{(Energy\ to\ HX)}{(Total\ Fuel\ Input)}$$

NOTE:

Combustion efficiency does not include losses from the boiler jacket. It is strictly a measure of the energy transferred from the products of combustion, and is determined directly by a fuel gas analysis.

Energy Efficiency Ratio (EER) *is the ratio of net cooling capacity (in Btu/hr) to total rate of electrical energy (in watts), of a cooling system under designated operating conditions, as determined using the applicable test method in the Appliance Efficiency Regulations or Section112*. An EER is typically used for larger packaged air conditioning equipment to express equipment efficiency. It is similar to IPLV.

$$EER = \frac{(Cooling\ Btu\ /\ hr)}{(Electric\ Input\ Watts)}$$

EER and COP are actually measurements of the same process, but are expressed in different units. They are related as:

$$COP = \frac{EER}{(3.413\ Btu\ /\ Watt)}$$

Energy Factor (EF) *is the ratio of energy output to energy consumption of a water heater, expressed in equivalent units, under designated operating conditions over a 24-hour use cycle, as determined using the applicable test method in the Appliance Efficiency Regulations.* It includes both the thermal efficiency of the heating process, as well as standby losses.

Fan Power Index is the hourly power consumption of the fan system per unit of air moved (Watts per cfm).

Integrated Part Load Value (IPLV) *is a single number of merit based on part load EER or COP expressing part load efficiency for air-conditioning and heat-pump equipment on the basis of weighted operation at various load capacities for the equipment as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112* . It is meant to approximate the 'typical' or annual operating efficiency of the equipment, much as an AFUE is used for heating equipment.

Seasonal Energy Efficiency Ratio (SEER) *means the total cooling output of a central air conditioner in British thermal units during its normal usage period for cooling divided by the total electrical energy input in watt-hours during the same period, as determined using the applicable test method in the Appliance Efficiency Regulations*

Thermal Efficiency is defined in the *Appliance Efficiency Regulations* as *a measure of the percentage of heat from the combustion of gas which is transferred to the water as measured under test conditions specified. . .* This definition applies to gas water heaters. In the *Standards*, this definition is generalized to include warm air furnaces.

$$\%\ Thermal\ Eff = \frac{(Energy\ to\ Medium)}{(Total\ Fuel\ Input)}$$

B. Definitions of Spaces and Systems

The concepts of spaces, zones, space-conditioning systems and systems are discussed in this subsection.

Spaces are not formally defined in the *Standards*, but are considered to be areas that are physically separated from each other with walls or other barriers. From a mechanical perspective, the barriers act to inhibit the free exchange of air with other spaces. The term "space" may be used interchangeably with "room."

Zone, Space Conditioning *is a space or group of spaces within a building with sufficiently similar* *comfort conditioning requirements so that comfort conditions, as specified in Section 144(b)3 or Section 150(h), as applicable, can be maintained throughout the zone by a single controlling device.* It is the designer's responsibility to determine the zoning; in most cases each building exposure will consist of at least one zone. Interior spaces that are not affected by outside weather conditions usually can be treated as a single zone.

A building will generally have more than one zone. For example, a facility having 10 spaces with similar conditioning that are heated and cooled by a single space-conditioning unit using one thermostat, is one zone. However, if a second thermostat and control damper, or an additional mechanical system, is added to separately control the temperature within any of the 10 spaces, then the building has two zones.

A **Space Conditioning System** *is a system that provides either collectively or individually heating, ventilating, or cooling within or associated with conditioned spaces in a building.* Exhaust fans are considered part of a space-conditioning system if they do not serve a process within the building, and are necessary for the proper operation of the space-conditioning system. Toilet exhausts are also included.

A space-conditioning system consists of only the components that must function together to deliver air to a given area; fans that can operate independently of each other comprise separate space-conditioning systems. For example, a building conditioned by 20 four-pipe fan coil units has 20 space-conditioning systems. If, instead, the building were supplied by a central fan system consisting of a supply fan, return fan and economizer, the building would have one space-conditioning system.

If more than one fan shares common air-controlling elements, then they are considered a single space-conditioning system. For example, if two supply fans share a common return fan and economizer, then both supply fans are part of the same space-conditioning system. Separate space-conditioning systems may share a common plenum and/or airshaft. For example, the four-pipe systems cited above may take air from a common plenum.

A **System** is a combination of equipment, controls, accessories, interconnecting means or terminal elements by which energy is transformed to perform a specific function, such as space conditioning, service water heating or lighting.

In the mechanical section, the term "system" will generally refer to one or more space-conditioning systems that are provided with heating and/or cooling energy by central boilers or chillers. As such, a building may have more than one system, and each system may include more than one space-conditioning system. The determining factor is whether any equipment is shared. For example, consider a building having four self-contained packaged rooftop units. This building has four space-conditioning systems, and four systems. If, however, the units were provided with hot and/or chilled water from a single central plant, then the building would have four space-conditioning systems, but only one system

C. Types of Air

Exhaust Air is air being removed from any space or piece of equipment and conveyed directly to the atmosphere by means of openings or ducts. The exhaust may serve specific areas, such as toilet rooms, or may be for a general building relief, such as an economizer.

Make-up Air is air provided to replace air being exhausted.

Mixed Air is a combination of return air and outdoor air. The outdoor air may be introduced to meet outdoor ventilation requirements, or to reduce mechanical cooling when the outdoor air conditions are suitable (see Section 4.1.2G).

Outdoor Air (Outside Air) *is air taken from outdoors and not previously circulated in the building.* For the purposes of ventilation, outdoor air is used to flush out pollutants produced by the building materials, occupants and processes. To ensure that all spaces are adequately ventilated with outdoor air, the

Standards require that each space be adequately ventilated (see Section 4.2.1D).

Return Air is air from the conditioned area that is returned to the conditioning equipment for reconditioning. The air may return to the system through a series of ducts, or through plenums and airshafts.

Supply Air is air being conveyed to a conditioned area through ducts or plenums from a heat exchanger of a heating, cooling, absorption or evaporative cooling system. Supply air is commonly considered air delivered to a space by a space-conditioning system. Depending on space requirements, the supply may be either heated, cooled or neutral.

Transfer Air is a way of meeting the ventilation requirements for spaces with different outdoor air requirements by allowing air to transfer from one space to another (see Section 4.2.1F).

D. Air Delivery Systems

Space-conditioning systems can be grouped according to how the airflow is regulated.

Constant Volume System is a space-conditioning system that delivers a fixed amount of air to each space. The volume of air is set during the system commissioning.

Variable Air Volume (VAV) System *is a space conditioning system that maintains comfort levels by varying the volume of conditioned air to the zones served.* This system delivers conditioned air to one or more zones. The duct serving each zone is provided with a motorized damper that is modulated by a signal from the zone thermostat.

Pressure Dependent VAV Box has an air damper whose position is controlled directly by the zone thermostat. The actual airflow at any given damper position is a function of the air static pressure within the duct. Because airflow is not measured, this type of box cannot control to either a maximum or minimum airflow.

Pressure Independent VAV Box has an air damper whose position is controlled on the basis of measured airflow. The setpoint of the airflow controller is, in turn, reset by a zone thermostat. A maximum and minimum airflow is set in the controller, and the box modulates between the two according to room temperature. Typically, when the zone temperature is at setpoint, the airflow will be halfway between the maximum and minimum airflow settings.

E. Attics and Return Plenums

Attics are unoccupied, unconditioned space located above the conditioned spaces, and outside of the insulated building envelope. Attics are usually closer to outdoor temperature than conditioned space temperature.

Return Air Plenum is an unoccupied space within the insulated building envelope through which air flows back to the space-conditioning system from the space(s). Return plenums are normally immediately above a ceiling, and below an insulated roof or the floor above. The return air temperature is usually within a few degrees of space temperature.

F. Zone Reheat, Recool and Air Mixing

When a space-conditioning system supplies air to one or more zones, different zones may be at different temperatures because of varying loads. Temperature regulation is normally accomplished by varying the conditioned air supply (variable volume), or by varying the temperature of the air delivered.

Reheat *is the heating of air that has been previously cooled by cooling equipment or systems or an economizer.* A heating device, usually a hot water coil, is placed in the zone supply duct and is controlled via a zone thermostat. Electric reheat is sometimes used, but is severely restricted by the *Standards*.

Recool *is the cooling of air that has been previously heated by space conditioning equipment or systems serving the same building.* A chilled water or refrigerant coil is usually placed in the zone supply duct and is controlled via a zone thermostat. Recooling is much less common than reheating.

Air Mixing consists of dampers regulating the flow of two separate air supplies to each zone, one heated and one cooled. The amount of each supply delivered to the zone is usually regulated by a zone thermostat. Occasionally, a third supply consisting of unconditioned, or "neutral" air, is also used.

G. Economizers

Air Economizer is a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical cooling [during mild or cool weather].

When the *Standards* require an economizer, the economizer must be integrated into the system so that it is capable of supplying part of the cooling load while the rest of the load is satisfied by the refrigeration equipment. The operation of an integrated air economizer is diagrammed in Figure 4-2. When outdoor air is sufficiently cold, the economizer satisfies all cooling demands on its own. As the outdoor temperature (or enthalpy) rises, or as system cooling loads increase, a point may be reached where the economizer is no longer able to satisfy the entire cooling load. At this point the economizer is supplemented by mechanical refrigeration, and both operate concurrently. Once the outside drybulb temperature (for temperature controlled economizer) or enthalpy (for enthalpy economizers) exceeds that of the return air or a predetermined high limit, the outside air intake is reduced to the minimum required, and cooling is satisfied by mechanical refrigeration only.

Nonintegrated economizers cannot be used to meet the economizer requirements of the prescriptive compliance approach. In nonintegrated economizer systems, the economizer may be interlocked with the refrigeration system to prevent both from operating simultaneously. The operation of a nonintegrated air economizer is diagrammed in Figure 4-3. Nonintegrated economizers can only be used if economizers are not required by the performance compliance.

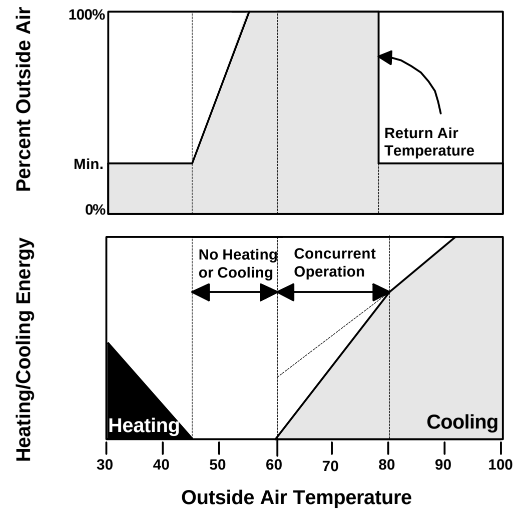


Figure 4-2: Integrated Air Economizer

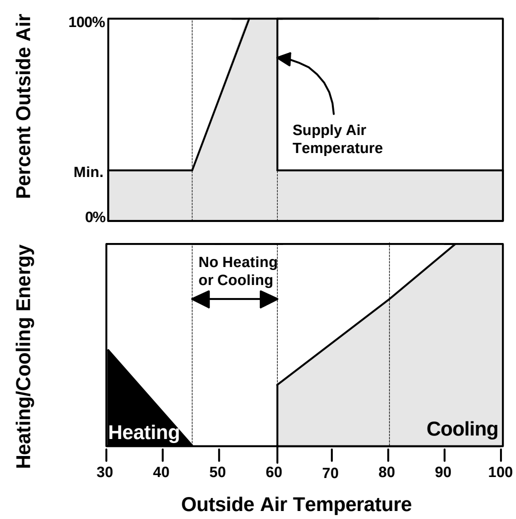


Figure 4-3: NonIntegrated Air Economizer

A **Water Economizer** is a system by which the supply air of a cooling system is cooled directly or indirectly by evaporation of water, or other appropriate fluid, in order to reduce or eliminate the need for mechanical cooling.

As with an air economizer, a water economizer must be integrated into the system so that the economizer can supply a portion of the cooling concurrently with the refrigeration system.

An example of a water economizer is shown in Figure 4.4. In this example, condenser water is cooled by the evaporative cooling tower to 50°F∀ during mild weather, and pumped first through the economizer coil to pre-cool the air. If the air is cooled sufficiently in this manner, the chiller stays off and water is diverted back to the tower. If additional cooling is required, the chiller starts and the air is cooled further, as required. If the weather is such that the tower water is hot (e.g., 75°F), water is diverted around the economizer coil to prevent the air from being heated.

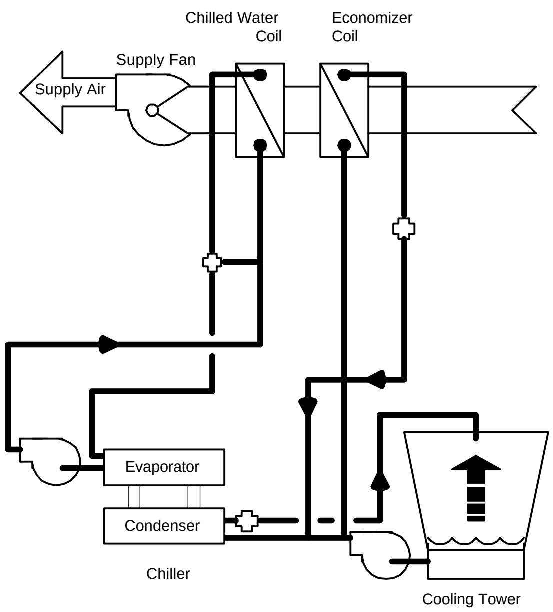


Figure 4-4: Water Economizer

H. Unusual Sources of Contaminants

Section 121 addresses ventilation requirements for buildings and uses the term of "unusual sources of contamination." In this context, such contaminants are considered to be chemicals, materials, processes or equipment that produce pollutants which are considered harmful to humans, and are not typically found in most building spaces. Examples may include some cleaning products, blueprint machines, heavy concentrations of cigarette smoke and chemicals used in various processes.

The designation of such spaces is left to the designer's discretion, and may include considerations of toxicity, concentration and duration of exposure. For example, while photocopiers and laser printers are known to emit ozone, scattered throughout a large space it may not be of concern. A heavy concentration of such machines in a small space may merit special treatment (See Section 4.2.1D)

I. Demand Control Ventilation

Demand control ventilation is allowed as an exception in the ventilation requirements for intermittently occupied systems Section 121(c)1. It is a concept in which the amount of outdoor air used to purge one or more offending pollutants from a building is a function of the measured level of the pollutant(s).

Carbon dioxide sensors measure the level of carbon dioxide, which is the primary pollutant produced by humans and other animals. This is the most common demand control ventilation device, and the only type called out in the *Standards*.

J. Intermittently Occupied Spaces

The demand control ventilation devices discussed above are allowed only in spaces that are intermittently occupied. An intermittently occupied space is considered to be an area which is infrequently or irregularly occupied by people, so that the periods of occupancy cannot be readily determined in advance. Examples may include bars, restaurants, assembly areas, rooms for long-term storage and equipment rooms. Spaces in which normal occupancy can reasonably be determined in advance, such as offices, do not fall in this category.

4.2 MECHANICAL DESIGN PROCEDURES

4.2.1 Mandatory Measures

The mandatory features and requirements for mechanical equipment must be included in the system design whether compliance is shown by the prescriptive or the performance approach. These features have been shown to be cost effective over a wide range of building types and mechanical systems.

It is worth noting that many of the mandatory features and devices, such as equipment efficiency, are requirements of the manufacturer. It is the responsibility of the designer, however, to specify products in the building design that meet these requirements.

Mechanical equipment subject to the mandatory requirements must:

1. Be certified by the manufacturer as complying with the efficiency requirements as prescribed in:

   Section 111 Appliances regulated by the Appliance Efficiency Regulations;

   Section 112 Space Conditioning;

   Section 113 Service Water Heating Systems and Equipment;

   Section 114 Pool and Spa Heating systems and Equipment;

   Section 115 Pilot Lights Prohibited

2. Be specified and installed in accordance with:

   Section 121 Requirements for Ventilation;

   Section 122 Required Controls for Space Conditioning Systems;

   Section 123 Requirements for Pipe Insulation;

   Section 124 Requirements for Ducts and Plenums.

A. Equipment Certification (§111-112)

Mechanical equipment installed in a building subject to these regulations must be certified as meeting certain minimum efficiency and control requirements. These requirements are contained in the Appliance Efficiency Regulations, and are also listed in Appendix B, Table B-9. The AFUE, COP, EER, IPLV, Combustion Efficiency, and Thermal Efficiency values of all equipment must be determined using the applicable test method specified in the Appliance Efficiency Regulations or Section 112:

1. Where more than one efficiency standard or test method is listed, the requirements of both shall apply. For example, both an EER and IPLV are listed for water-cooled air conditioners. This means that the air conditioner must have a rated EER equal to or higher than that specified at Air-Conditioning and Refrigeration Institute (ARI) standard rating conditions, and must also have an annual IPLV equal to or higher than that specified using ARI's assumed operating profiles (Section 112(a)1 & 2).

2. Where equipment can serve more than one function, such as both heating and cooling, or space heating and water heating, it must comply with the requirements applicable to each function.

3. Where a requirement is for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the capacity shall be as provided for and allowed by the controls during steady state operation. For example, a boiler with Hi/Lo firing must meet the efficiency requirements when operating at both its maximum capacity and minimum capacity (Section 112(a)4).

Small appliances such as room air conditioners, gas space heaters and small water heaters, are regulated through the Appliance Efficiency Regulations found in

Title 20, Chapter 2, Subchapter 4, Article 4 of the California Code of Regulations. To comply, manufacturers must certify to the Energy Commission that their equipment meets minimum standards.

Example 4-1: Efficiency Compliance

Question

If a gas-pack with 15 tons cooling and 260,000 Btu/hr maximum heating capacity has an EER = 8.7, an IPLV = 7.6 and a heating efficiency of 78 percent, does it comply?

Answer

No. The cooling side complies because the EER and IPLV both exceed the requirements. However, the heating efficiency must be at least 80 percent; therefore the unit does not comply. (See Appendix B Table B-9)

Example 4-2: Efficiency Compliance

Question

A 500,000 Btu/hr gas-fired boiler with Hi/Lo firing has a full load combustion efficiency of 82 percent, and a Lo-fire combustion efficiency of 80 percent. Does the unit comply?

Answer

Yes. The combustion efficiency is at least 80 percent at both the maximum- and minimum-rated capacity (see Appendix B, Table B-9).

Larger equipment not covered by the Appliance Efficiency Regulations is regulated by Section 112 of the Standards. To comply, equipment specified in the plans and specifications must meet the minimum standards mandated in that section. Manufacturers of equipment not regulated by the Appliance Efficiency Regulations are not required to certify their equipment to the Energy Commission; it is the responsibility of the designer and contractor to specify and install equipment that complies.

B. Control Equipment Certification (§119(d) & §121(c)1)

In addition to the mechanical equipment discussed above, the following control devices must be certified to the Energy Commission prior to specification or use:

1. **Occupancy Sensors** - per Section 119(d).

2. **Demand Controls Ventilation** - per Section 121(c)1 Exception No. 1.

NOTE:

Automatic time switches must meet the requirements of Section 119(c). When used solely for mechanical controls they are not required to be certified.

C. Pilot Lights (§115)

Pilot lights are prohibited in:

1. Pool and spa heaters (Section 114(a)5).

2. Household cooking appliances unless the appliance does not have an electrical connection, and the pilot consumes less than 150 Btu/hr (Section 115(b)).

3. Fan type central furnaces. This includes all space-conditioning equipment that distributes gas-heated air through duct work (Section 115(a)). This prohibition does not apply to radiant heaters, unit heaters, boilers or other equipment that does not use a fan to distribute heated air.

D. Outdoor Ventilation - General Requirements (§121)

Ventilation Scope

Within a building all enclosed spaces that are normally used by humans must be continuously ventilated during occupied hours with outdoor air using either natural or mechanical ventilation (Section 121(a)1).

NOTE:

The *Standards* highly recommend that spaces that may have unusual sources of contaminants be designed with enclosures to contain the contaminants, and local exhaust systems to directly vent the contaminants outdoors (Section 121(a)1).

The designation and treatment of such spaces is subject to the designer's discretion. Spaces needing special consideration may include:

- Commercial and coin-operated dry cleaners
- Bars and cocktail lounges
- Smoking lounges and other designated smoking areas
- Beauty and barber shops
- Auto repair workshops
- Print shops, graphic arts studios and other spaces where solvents are used in a process
- Copy rooms, laser printer rooms or other rooms where it is expected that equipment may generate heavy concentrations of ozone or other contaminants

"Spaces normally used by humans" refers to spaces where people can be reasonably expected to remain for an extended period of time. Spaces where occupancy will be brief and intermittent, and that do not have any unusual sources of air contaminants, do not need to be directly ventilated. For example:

1. A **closet** does not need to be ventilated provided it is not normally occupied.
2. A **storeroom** that is only infrequently or briefly occupied does not require ventilation. However, a storeroom that can be expected to be occupied for extended periods for clean-up or inventory must be ventilated, preferably with systems controlled by a local switch so that the ventilation system operates only when the space is occupied.

E. Natural Ventilation (§121(b)1)

Natural outdoor ventilation may be provided for spaces where all areas of the space are within 20 feet of an operable wall or roof opening through which outdoor air can flow. The sum of the areas of the openings must total at least 5 percent of the floor area of each space that is naturally ventilated. The openings must also be readily accessible to the occupants of the space at all times.

Airflow through the openings must come directly from the outdoors; air may not flow through any intermediate spaces such as other occupied spaces, unconditioned spaces, corridors, or atriums. High windows or operable skylights should be accessible from the floor.

Example 4-3: Natural Ventilation

Question

What is the window area required to ventilate a 30' x 32' classroom?

Answer

In order for all points to be within 20 feet of an opening, windows must be evenly divided between two opposing walls. The area of the openings must be:

(32 feet x 30 feet) x 5% = 48 square feet

The actual window area must be at least 96 square feet if only half the window can be open at a time.

Calculations must be based on free area, Taking into account framing, the actual window area is approximately 100 square feet.

F. Mechanical Ventilation (§121(b)2 and (d))

Mechanical outdoor ventilation must be provided for all spaces normally used by humans that are not naturally ventilated. In the discussion that follows, the term *ventilation air* is interchangeable with 'outdoor ventilation' or 'outdoor air.' *Supply air* means the total amount of air supplied to a space, and includes both recirculated and outdoor air.

Supply Air is air being conveyed to a conditioned area through ducts or plenums from a heat exchanger of a heating, cooling, absorption or evaporative cooling system. Supply air is commonly considered air delivered to a space by a space-conditioning system. Depending on space requirements, the supply may be either heated, cooled or neutral.

Each *space* requiring mechanical ventilation shall be provided with outdoor air at a design rate that is the greater of either Table 4-2 or of the two methods listed below.

Table 4-1a: Minimum Ventilation Rates

Type of Use	CFM / SF Conditioned Floor Area
Auto Repair Workshops	1.50
Barber Shops	0.40
Bars, Cocktail Lounges, and Casinos	1.50
Beauty Shops	0.40
Coin-Operated Cry Cleaning	0.30
Commercial Dry Cleaning	0.45
High Rise Residential	Per UBC Section 1205
Hotel Guest Rooms (< 500 sf)	30 CFM per Guest Room
Hotel Guest Rooms (> or = 500 sf)	0.15
Retail Stores	0.20
Smoking Lounges	1.50
All Others	0.15

1. The **conditioned floor area of the space**, multiplied by the applicable minimum ventilation rate from Table 4-1a.

2. 15 cfm per person, multiplied by the expected number of occupants. For spaces with fixed seating (such as a theater or auditorium), the expected number of occupants as determined in accordance with Chapter 10 of the Uniform Building Code (UBC) is the number of fixed seats. For spaces without fixed seating, the expected number of occupants is assumed to be no less than one-half the maximum occupant load assumed for exiting purposes in Chapter 10 of the UBC. Table 4-1b shows the typical maximum occupant loads for various building uses upon which minimum ventilation calculations are based.

Each *space-conditioning system* must provide outdoor ventilation air as follows:

1. For a space-conditioning system serving a single space, the required system outdoor air flow is equal to the design outdoor ventilation rate of the space.

2. For a space-conditioning system serving multiple spaces, the required outdoor air quantity delivered by the space-conditioning system must be not less than the sum of the required outdoor ventilation rate to each space.

   The *Standards* do not require that each space actually receive its calculated outdoor air quantity (Section 121(b)2 Exception.) Instead, the actual supply to any given space may be any combination of recirculated air, outdoor air, or air transferred directly from other spaces, provided:

   a. The total amount of outdoor air delivered by the space-conditioning system(s) to all spaces is at least as large as the sum of the space design quantities

   b. Each space always receives a supply airflow, including recirculated air and/or transfer air, no less than the calculated outdoor ventilation rate

   c. When using transfer air, none of the spaces from which air is transferred has any unusual sources of contaminants

Table 4-1b: UBC 1997 Occupant Densities (sf/person)

Uniform Building Code Occupant Densities

USE / APPLICATION	OCCUPANT LOAD FACTOR	USE / APPLICATION	OCCUPANT LOAD FACTOR
Aircraft Hangars	500	Courtrooms	40
Auction Room	7	Dormitories	50
ASSEMBLY AREAS		Dwellings	300
Auditoriums	7	Garage Parking	200
Churches/Chapels	7	Healthcare Facilities	
Lobbies	7	Sleeping Rooms	120
Lodge Rooms	7	Treatment Rooms	240
Reviewing Stands	7	Hotel/Apartments	200
Stadiums	7	Kitchens - Commercial	200
Waiting Areas	3	Library	
Conference Room	15	Reading Rooms	50
Dining Rooms	15	Stack Areas	100
Drinking Rooms	15	Locker Room	50
Exhibit Rooms	15	Malls (see UBC chpt.4)	--
Gymnasiums	15	Manufacturing Areas	200
Lounges	15	Mechanical Equipment Rooms	300
Stages	15	Day Care	35
Gaming: Keno, Slot Machine and Live Games Area	11	Offices	100
		School Shops/Vocational Rooms	50
Bowling Alley (assume no occupants for lanes)	5/alley+15ft runway	Skating Rinks	50 Skate Area/ 15 on Deck
Children's Home	80	Storage/Stock Rooms	300
Home for Aged	80	Stores – Retail Sales Room	
Classrooms	20	Basements and Ground Floor	30
Congregate Residences	200	Upper Floors	60
Accommodating 10 or less persons and having an area of 3,000 sq.ft. or less		Swimming Pools	50 Pool Area/ 15 on Deck
		Warehouses	500
		All Others	100

Table 4-2: Required Minimum Ventilation Rate Per Occupancy

Occupancy / Use	UBC Table No. 10-A		Choose Largest		
	Sf/ Occupant	Number of People per 1000 sf	Ventilation CEC STD Table 1-F CFM/sf	UBC Based Ventilation CFM/sf	Req. Vent CFM/sf (largest)
1) Aircraft Hangars	500	2	0.15	0.02	0.15
2) Auction Rooms	7.0	143	0.15	1.07	1.07
3) Assembly Areas (Concentrated Use)					
Auditoriums	7.0	143	0.15	1.07	1.07
Bowling Alleys	4.0	250	0.15	1.88	1.88
Churches & Chapels (Religious Worship)	7.0	143	0.15	1.07	1.07
Dance Floors	7.0	143	0.15	1.07	1.07
Lobbies	7.0	143	0.15	1.07	1.07
Lodge Rooms	7.0	143	0.15	1.07	1.07
Reviewing Stands	7.0	143	0.15	1.07	1.07
Stadiums	7.0	143	0.15	1.07	1.07
Theaters - All	7.0	143	0.15	1.07	1.07
Waiting Areas	3.0	333	0.15	2.50	2.50
4) Assembly Areas (Nonconcentrated Use)	15.0	67	0.15	0.50	0.50
Conference & Meeting Rooms (1)	15.0	67	0.15	0.50	0.50
Dining Rooms/Areas	15.0	67	0.15	0.50	0.50
Drinking Establishments (2)	15.0	67	1.50	0.50	1.50
Exhibit/Display Areas	15.0	67	0.15	0.50	0.50
Gymnasiums/Sports Arenas	15.0	67	0.15	0.50	0.50
Lounges	15.0	67	1.50	0.50	1.50
Stages	15.0	67	1.50	0.50	1.50
Gaming, Keno, Slot Machine and Live Games Areas	11.0	91	1.50	0.68	1.50
5) Auto Repair Workshops	100.0	10	1.50	0.08	1.50
6) Barber & Beauty Shops	100.0	10	0.40	0.08	0.40
7) Children's Homes & Homes for Aged	80.0	13	0.15	0.09	0.15
8) Classrooms	20.0	50	0.15	0.38	0.38
9) Courtrooms	40.0	25	0.15	0.19	0.19
10) Dormitories	50.0	20	0.15	0.15	0.15
11) Dry Cleaning (Coin-Operated)	100.0	10	0.30	0.08	0.30
12) Dry Cleaning (Commercial)	100.0	10	0.45	0.08	0.45
13) Garage, Parking	200.0	5	0.15	0.04	0.15
14) Healthcare Facilities: Sleeping Rooms	120.0	8	0.15	0.06	0.15
Treatment Rooms	240.0	4	0.15	0.03	0.15
15) Hotels and Apartments	200.0	5	0.15	0.04	0.15
Hotel Function Area (3)	15.0	67	0.15	0.50	0.50
Hotel Lobby	100.0	10	0.15	0.08	0.15
Hotel Guest Rooms (<500 sf)	200.0	5	Footnote 4	0.04	Footnote 4
Hotel Guest rooms (>=500 sf)	200.0	5	0.15	0.04	0.15
Highrise Residential	200.0	5	0.15	0.04	0.15
16) Kitchen(s)	200.0	5	0.15	0.04	0.15
17) Library : Reading Rooms	50.0	20	0.15	0.15	0.15
Stack Areas	100.0	10	0.15	0.08	0.15
18) Locker Rooms	50.0	20	0.15	0.15	0.15
19) Manufacturing	200.0	5	0.15	0.04	0.15
20) Mechanical Equipment Room	300.0	3	0.15	0.03	0.15
21) Nurseries for Children - Day Care	50.0	20	0.15	0.15	0.15
22) Offices: Office	100.0	10	0.15	0.08	0.15
Bank/Financial Institution	100.0	10	0.15	0.08	0.15
Medical & Clinical Care	100.0	10	0.15	0.08	0.15
23) Retail Stores (See Stores)					
24) School Shops & Vocational Rooms	50.0	20	0.15	0.15	0.15
25) Skating Rinks: Skate Area	50.0	20	0.15	0.15	0.15
On Deck	15.0	67	0.15	0.50	0.50
26) Stores : Retail Sales, Wholesale Showrooms	30.0	33	0.20	0.25	0.25
Basement and Ground Floor	30.0	33	0.20	0.25	0.25
Upper Floors	60.0	17	0.20	0.13	0.20
Grocery	30.0	33	0.20	0.25	0.25
Malls, Arcades, & Atria	30.0	33	0.20	0.25	0.25
27) Swimming Pools : Pool Area	50.0	20	0.15	0.15	0.15
On Deck	15.0	67	0.15	0.50	0.50
28) Warehouses, Industrial & Commercial Storage/Stockrooms (see 4.2.1 b)	500.0	2	0.15	0.02	0.15
29) All Others -- Including Unknown	100.0	10	0.15	0.08	0.15
Corridors, Restrooms, & Support Areas	100.0	10	0.15	0.08	0.15
Commercial & Industrial Work	100.0	10	0.15	0.08	0.15

Footnotes:
1) Convention, Conference, Meeting Rooms
2) Bars, Cocktail & Smoking Lounges, Casinos
3) See Conference Rooms or Dining Rooms
4) Guestrooms less than 500 sf use 30 cfm/guestroom

Equations used to find:

1)
$$\text{Number of People per 1000sf} = \frac{1000}{\text{Sf/Occupant}}$$

2)
$$\text{UBC Based Ventilation CFM/sf} = \left(\frac{\frac{\text{Number of People per 1000sf}}{1000}}{2}\right) \times 15 \text{ CFM}$$

The concept of transfer and/or recirculated air is very important, because it allows a single space-conditioning system to serve areas requiring different fractions of outdoor air in their supplies. Rather than establishing the outdoor ventilation rate on the basis of the zone requiring the *highest* outdoor air fraction, this exception allows the ventilation rate to be based on the *average* required by all spaces served by the system.

Required ventilation rates for a two-space building are illustrated in Example 4-4. When each space is served by a separate constant volume system, the calculation and application of ventilation rate is straightforward, and each space will always receive its design outdoor air quantity. However, a central system serving both spaces does not deliver the design outdoor air quantity to each space. Instead, one space receives more than its allotted share, and the other less. This is because the training room has a higher design outdoor ventilation rate and/or a lower cooling load relative to the other space. The *Standards* permit this, provided the system meets the requirements described in items 2a, 2b and 2c above.

The *Standards* allow this compromise in recognition of the difficulty in positively ensuring that each space is always ventilated at the design rate, particularly when variable air volume (VAV) systems are used and/or the future location of conference rooms and other tenant improvements are not known. The *Standards* also implicitly recognize that the building will be adequately ventilated in most cases as long as the total system ventilation rate is sufficient.

Example 4-4: Ventilation for a Two-room Building

Question

Consider a building with two spaces, each having an area of 1,000 square feet. One space is used for general administrative functions, and the other is used for classroom training. It is estimated that the office will contain seven people, and the classroom will contain 50 (fixed seating). What are the required outdoor ventilation rates?

Answer

1. *For the office area, the design outdoor ventilation air is the larger of:*

   7 people x 15 cfm/person = 105 cfm

   or

   1,000 sf x 0.15 cfm/sf = 150 cfm

   For this space, the design ventilation rate is 150 cfm.

2. *For the classroom, the design outdoor ventilation air is the larger of:*

   50 people x 15 cfm/person = 750 cfm

   or

   1,000 sf x 0.15 cfm/sf = 150 cfm

   For this space the design ventilation rate is 750 cfm.

Assume the total supply air necessary to satisfy cooling loads is 1000 cfm for the office and 1,500 cfm for the classroom. If each space is served by a separate system, then the required outdoor ventilation rate of each system is 150 cfm and 750 cfm, respectively. This corresponds to a 15 percent outside air (OA) fraction in the office HVAC unit, and 50 percent in the classroom unit.

If both spaces are served by a central system, then the total supply will be (1,000 + 1,500) cfm = 2500 cfm. The required outdoor ventilation rate is (150 + 750) = 900 cfm total. The actual outdoor air ventilation rate for each space is:

Office OA = 900 cfm x (1,000 cfm / 2,500 cfm) = 360 cfm

Classroom OA = 900 cfm x (1,500 cfm / 2,500 cfm) = 540 cfm

While the actual OA cfm to the classroom is less than design (540 cfmvs. 750 cfm), the Standards allow this provided that the system always delivers at least 750 cfm to the classroom (including transfer or recirculated air), and that any transfer air is free of unusual contaminants.

The *Standards* specify the minimum outdoor ventilation rate to which the system must be designed. If desired, the designer may elect to take a more conservative approach. For example, the design outdoor ventilation rate may be determined using the procedures described in ASHRAE 62-1989, provided the resulting outdoor air quantities are no less than required by these *Standards*.

Direct Air Transfer

As described above, the *Standards* allow air to be directly transferred from other spaces as part of the "outdoor" supply to a space. The actual percentage of outdoor air present in the transfer air need not be taken into account as long as the total outdoor quantity required by all spaces is provided by the mechanical system. This method can be used for any space, but is particularly applicable to conference rooms and other rooms that have high ventilation requirements. Transfer air must be free from any unusual contaminants, and as such should not be taken directly from rooms where such sources of contaminants are anticipated.

Air may be transferred using any method that ensures a positive airflow. Examples include dedicated transfer fans, exhaust fans and fan-powered VAV boxes. A system having a ducted return may be balanced so that air naturally transfers into the space. Exhaust fans serving the space may discharge directly outdoors, or into a return plenum. Transfer systems should be designed to minimize recirculation of transfer air back into the space; duct work should be arranged to separate the transfer air intake and return points. When the location of conference rooms and other areas requiring high ventilation rates are known in advance, it is recommended that these spaces be provided with separate sources of outdoor air. Note also that other codes may restrict from where transfer air may be taken. For example, transfer air cannot be drawn from a fire-resistive corridor used for exit purposes. Transfer air can be transported through fire-rated partitions provided all code requirements, such as the use of fire and/or smoke dampers, are met.

Distribution of Outdoor Air to Zonal Units (§121(d))

When a zonal heating or cooling unit is located in a plenum and an outdoor supply is not directly connected to the unit, then the outdoor air must be ducted to discharge either:

1. Within five feet of the unit; or

2. Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute.

Water source heat pumps and fan coils are the most common application of this configuration. The unit fans should be controlled to run continuously during occupancy in order for the ventilation air to be circulated to the occupied space.

A central space-conditioning system(s) augmented by a few zonal units for spot conditioning may use transfer air from spaces served by the central system. A direct source of outdoor air is not required for each zonal unit. Similarly, transfer air may be used in buildings having central interior space-conditioning systems with outdoor air, and zonal units on the perimeter (without outdoor air).

While not required, the *Standards* recommend that sources of unusual contaminants be controlled through the use of containment systems that capture the contaminants and discharge them directly outdoors. Such systems may include exhaust hoods, fume hoods, small space exhausts and differential pressure control between spaces. The designer is advised to consult ASHRAE handbooks or other publications for guidance in this subject.

G. *Ventilation System Operation and Controls (§121(c))*

Outdoor Ventilation Air and VAV Systems

The *Standards* require that the minimum rate of outdoor air calculated per Section 121(b)2 be provided to each space *at all times* when the space is usually occupied (Section 121(c)1). For spaces served by VAV systems, this implies that the minimum supply setting of each VAV box should be no less than the design outdoor ventilation rate calculated for the space, unless transfer air is used. If transfer air is used, the minimum box position, plus the transfer air, should meet the minimum ventilation rate. If transfer air is not used, the box should be controlled so that the minimum required airflow is maintained at all times. With either strategy, the box should have pressure-independent controls; pressure dependent controls cannot ensure that ventilation is maintained because they do not measure airflow. See Example 4-5.

The design outdoor ventilation rate at the system level must always be maintained when the space is occupied, even when the fan has modulated to its minimum capacity (Section 121(c)1). Therefore, a means of continuously providing at least the minimum amount of outdoor air should be incorporated into the design of the system. Such means may include:

1. Separate outdoor air fans with modulating controls that introduce a fixed amount of air into the return or mixed air sections of the system; or

2. Controls that maintain a fixed differential between supply and return fan air flow rates. The differential may be measured with air flow stations, or determined during commissioning via an air balance, taking multiple measurements of flow at different fan capacities; or

Example 4-5: Minimum VAV CFM

Question

If the minimum required outdoor ventilation rate for a space is 150 cfm, what is the minimum allowed airflow for a 1000 cfm VAV box when the designed percentage of outdoor air in the supply is 20 percent?

Answer

The ventilation standard requires that every space in a building be designed to have outdoor air ventilation Section 121 (b)). Based on the design criteria, the total circulated air volume in this case will be 750 cfm (150/0.20). However, the outside air supply can be up to 100 percent of the total supply. Additionally, the minimum allowed airflow may be as low as 150 cfm provided that enough outdoor air is supplied to all spaces combined to meet the requirements of Section 121(b)2 for each space individually.

3. Exhaust fans, including toilet exhausts, that exhaust a fixed amount of air from the building during all occupied hours; or

4. Outside air dampers having minimum settings that vary with fan capacity. This will necessitate an air balance taking multiple measurements of outdoor air flow in comparison to fan capacity so that a curve can be developed. A controller capable of being programmed with the curve will be critical, as is some means of measuring fan capacity. Capacity can be measured by an air flow station, or correlated to an inlet vane signal, a variable frequency drive (VFD) signal, or fan motor amps; or

5. Balancing the space-conditioning system to provide the required outdoor ventilation at the minimum expected supply airflow.

   If the space-conditioning system incorporates an air economizer, the balance may be made at the expected supply airflow corresponding to the conditions at which the economizer closes to minimum. For example, assume the economizer closes to minimum at an outdoor temperature of 70°F. Below this temperature, the economizer will usually be delivering more than the minimum outdoor ventilation rate in order to satisfy space cooling loads. Therefore, the operating point of concern for the minimum outdoor damper setting corresponds to the supply airflow normally expected at 70°F.

For systems that do not have a return fan, the actual outdoor ventilation rate will increase as the fan supply increases and the static pressure on the suction side of the fan drops. In this case, the load calculations and equipment sizes as documented on the compliance forms must be based on the outdoor ventilation rate expected at design conditions, and not the minimum as calculated in this section.

Since this approach can force equipment to be larger than otherwise required and may also waste energy, other solutions are preferred; or

6. Provide dedicated intake and supply fans designed to meet minimum ventilation requirements; or

7. Other methods approved by the enforcement agency.

Pre-Occupancy

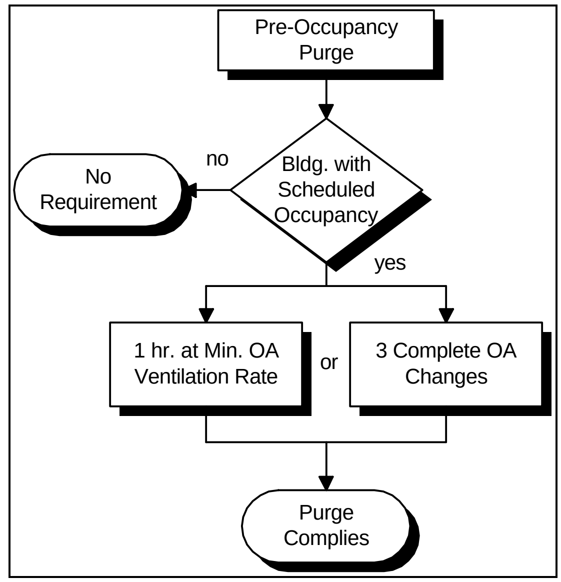
Since many indoor air pollutants are outgassed from the building materials and furnishings, the *Standards* require that buildings having a scheduled operation be purged before occupancy (Section 121(c)2). In the hour immediately prior to occupancy, outdoor ventilation must be provided at a rate equal to the lesser of :

1. The minimum required ventilation rate; or

2. Three complete air changes per hour.

The first criteria will normally apply to office spaces when the outdoor damper is in the minimum ventilation position. The second criteria would apply to spaces having higher ventilation rates, or to offices if the purge is accomplished by using an economizer with dampers fully open. *Three complete air changes* means an amount of ventilation air equal to three times the volume of the occupied space. This air may be introduced at any rate provided for and allowed by the system, so that the actual purge period may be less than an hour.

Figure 4-5: Pre-Occupancy Purge Flowchart



A pre-occupancy purge is not required for buildings or spaces that are not occupied on a scheduled basis, such as storage rooms. Also, a purge is not required for spaces provided with natural ventilation.

Example 4-6: Purge Period

Question

What is the length of time required to purge a space 10 feet high with an outdoor ventilation rate of 1.5 cfm/sf?

Answer

For 3 air changes, each square foot of space must be provided with:

OA volume = 3 x 10 = 30 cubic feet

At a rate of 1.5 cfm/sf, the time required is:

Time = 30 cf / 1.5 cfm/sf = 20 minutes

Example 4-7: Purge with Natural Ventilation

Question

In a building with natural ventilation, do the windows need to be left open all night to accomplish a building purge?

Answer

No. A building purge is required only for buildings with mechanical ventilation systems.

Example 4-8: Purge with Occupancy Timer

Question

How is a purge accomplished in a building without a regularly scheduled occupancy whose system operation is controlled by an occupancy sensor?

Answer

There is no purge requirement for this building. Note that occupancy sensors and manual timers can only be used for system control in buildings that are intermittently occupied.

NOTE:

Many programmable control systems have as part of their standard package a control sequence called *Optimized Start.* This logic will calculate how far in advance of occupancy the HVAC system must start so that the space temperature is at setpoint at time of occupancy. To maximize energy savings, this logic typically keeps the outside air dampers closed until occupancy. Programming in control systems using this logic should be modified to incorporate a building purge in accordance with these requirements

Demand Control Ventilation

As described in Section 121(b)2, outdoor ventilation requirements are based on either a cfm/sf requirement or 15 cfm per person, whichever is larger. If the design occupant density is the determining factor, and the actual number of people is often less than design, then the HVAC system will frequently be conditioning unnecessarily large amounts of outdoor air.

The outdoor ventilation rate in these types of facilities can be reduced by a demand control ventilation device, provided:

1. The device is certified to the Energy Commission; and

2. If the device is a CO_2 sensor, it limits the CO_2 level to no more than 800 parts per million (ppm) while the space is occupied; and

3. The sensor for the device is located either in the space or in the return air from the space, with no less than one sensor for every 25,000 square feet of habitable space, or no more space than is recommended by the manufacturer, whichever is less.

The controls must not allow the effective ventilation rate to drop below 0.15 cfm per square foot.

Examples of suitable applications for demand ventilation controls include restaurants, hotel ballrooms, meeting rooms, lecture halls, etc. Offices and other spaces having occupant densities less than 10 people per 1,000 square feet would not be good applications as the cfm per square foot requirement exceeds the cfm per person requirement.

Fan Cycling

While Section 121(c) requires that ventilation be continuous during normally occupied hours, Exception No. 2 allows the ventilation to be disrupted for not more than five minutes out of every hour. In this case the ventilation rate during the time the system is ventilating must be increased so the average rate over the hour is equal to the required rate.

This restriction limits the duty cycling of fans by energy management systems to not more than five minutes out of every sixty. In addition, when a space-conditioning system that also provides ventilation is controlled by a thermostat incorporating a fan “On/Auto” switch, the switch should be set to the “On” position. Otherwise, during mild conditions, the fan may be off the majority of the time.

Variable Air Volume (VAV) Changeover Systems

Some VAV systems provide conditioned supply air, either heated or cooled, through a single set of ducting. These systems are commonly referred to as "single duct VAV systems." In the event that heating is needed at the same time that cooling is needed in one or more different spaces, the system must alternate between supplying heated and cooled air. When the supply air is heated, for example, the spaces requiring cooling are isolated (cut off) by the VAV dampers and must wait until the system switches back to cooling mode.

Systems of this type do not meet the ventilation requirements unless provisions are incorporated to ensure that the required ventilation to each space is disrupted no more than five minutes every hour. This may require that the controls incorporate a minimum damper position setting for each zone. Alternatively, natural ventilation or other ventilation mechanisms can be provided.

Adjustment of Ventilation Rate

Section 121(c) specifies the minimum required outdoor ventilation rate, but does not restrict the maximum. However, if the designer elects to have the space-conditioning system operate at a ventilation rate higher than the rate required by the *Standards*, then the *Standards* require that the space-conditioning system must be adjustable so that in the future the ventilation rate can be reduced to the amount required by the *Standards* or the rate required for make-up of exhaust systems that are required for a process, for control of odors, or for the removal of contaminants within the space Section 121(e)).

In other words, a system can be designed to supply higher than minimum outside air volumes provided dampers or fan speed can be adjusted to allow no more than the minimum volume if, at a later time, someone decides it is desirable. The *Standards* preclude a system designed for 100 percent outdoor air, with no provision for any return air, unless the supply air quantity can be adjusted to be equal to the design minimum outdoor air volume. The intent is to prevent systems from being designed that will permanently over ventilate spaces.

Miscellaneous Dampers (§122(f))

Dampers should not be installed on combustion air intakes, or where prohibited by other provisions of law (Section 122(f) Exception Nos. 3 & 4). If the designer elects to install dampers on shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in accordance with applicable fire codes.

Completion and Balancing (§121(f))

Before an occupancy permit is granted for a new building or space, or before a new space-conditioning or ventilating system serving a building or space is operated for normal use, the mechanical ventilation system serving the building or space must be documented in accordance with Title 8, Section 5142(b) of the California Safety Code (1987) to be providing no less than the ventilation rate required by the *Standards* as determined using one of the following procedures:

1. Balancing: The system shall be balanced in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983), or Associated Air Balance Council (AABC) National Standards (1989); or

2. Outside Air Certification: The system shall provide the minimum outside air as shown on the mechanical drawings, and shall be measured by the installing licensed C-20 mechanical contractor and certified by either the design mechanical engineer, the installing licensed C-20 mechanical contractor, or the person with overall responsibility for the design of the ventilation system; or

3. Outside Air Measurement: The system shall be equipped with a calibrated local or remote device capable of measuring the quantity of outside air on a continuous basis and displaying that quantity on a readily accessible display device; or

4. Another method approved by the Energy Commission.

> NOTE:
>
> Additional code requirements may also apply in some areas of California, such as for the City of Los Angeles. This certification is regarded as “documentation in writing” and becomes the “first record” required by Title 8 of the new building.

Example 4-9: Maintenance of Ventilation System

Question

In addition to these commissioning requirements for the ventilation system, are there any periodic requirements for inspection?

Answer

These Standards do not contain any such requirements. However, Section 5142 of the General Industry Safety Orders, Title 8, California Safety Code (1987): Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation, states the following:

(b) Operation and Maintenance

(1) The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time.

(2) Inspections and maintenance of the HVAC systems shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years.

(3) The employer shall make all records required by this section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division (as defined in Section 3207 of Title 8), to any employee of the employer affected by this section, and to any designated representative of said employee of the employer affected by this section.

H. Required Controls for Space Conditioning Systems (§122)

This section covers controls that are mandatory for all system types, including:

1. Zoning and thermostatic control,

2. Shut-off and temperature setup/setback of space-conditioning systems, and

3. Off-hours space isolation.
   Zone Thermostatic Control (Section 122(a), (b) and (c))

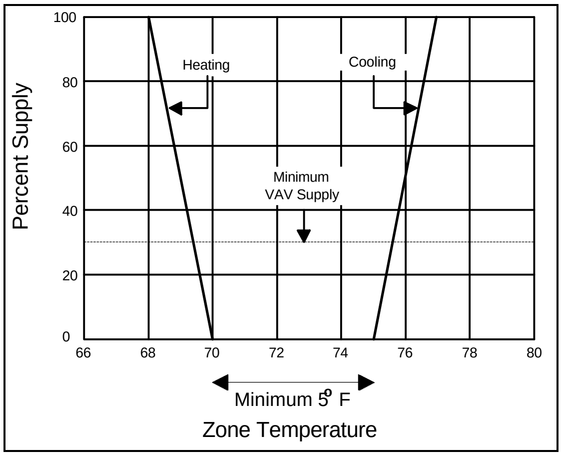
A thermostat must be provided for each *space-conditioning zone* or dwelling unit to control the supply of heating and cooling energy within that zone (Section 122(a)). The thermostat must have the following characteristics:

1. When used to control **heating**, the thermostat must be adjustable down to 55°F or lower.

2. When used to control **cooling**, the thermostat must be adjustable up to 85°F or higher.

3. When used to control both **heating and cooling**, the thermostat must be adjustable
4. from 55°F to 85°F and also provide a temperature range or **dead band** of at least 5°F. When the space temperature is within the deadband, heating and cooling energy must be shut off or reduced to a minimum. A dead band is not required if the thermostat requires a manual changeover between the heating and cooling modes Section 122(b) Exception No. 1).

Figure 4-6: Proportional Control Zone Thermostat



The setpoint may be adjustable either locally or remotely, by continuous adjustment or by selection of sensors.

Example 4-10: Direct Digital Control of Space Temperature

Question
Can an energy management system be used to control the space temperatures?
Answer
Yes, provided the space temperature setpoints can be adjusted, either locally or remotely.

Thermostats with adjustable setpoints and deadband capability are not required for zones that must have constant temperatures to prevent the degradation of materials, a process, or plants or animals Section 122(b) Exception No. 2). Included in this category are computer rooms, clean rooms, hospital patient rooms, museums, etc.

Hotel/Motel Guest Rooms and High-Rise Residential Dwellings Thermostats

The *Standards* require that thermostats in hotel and motel guest rooms have:

1. **Numeric temperature setpoints** in °F, and
2. **Setpoint stops** that prevent the thermostat from being adjusted outside the normal comfort range. These stops must be concealed so that they are accessible only to authorized personnel.

The *Standards* effectively prohibit thermostats having ‘warmer/cooler’ or other labels with no temperature markings in this type of occupancy (Section 122(c)).

The *Standards* require (Section 122(c)) that thermostats in High-rise residential dwelling units must have setback capabilities and meet all the requirements in Section 150(i).

Perimeter Systems Thermostats

Supplemental perimeter heating or cooling systems are sometimes used to augment a space-conditioning system serving both interior and perimeter zones. Section 122(a) Exception allows this, provided controls are incorporated to prevent the two systems from conflicting with each other. In this case, the *Standards* require that:

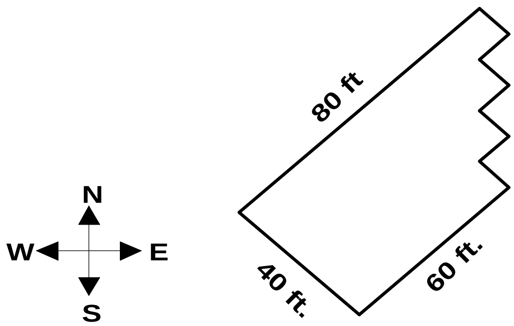
1. The perimeter system must be designed solely to offset envelope heat losses or gains; and
2. The perimeter system must have at least one thermostatic control for each building orientation of 50 feet or more; and
3. The perimeter system is controlled by at least one thermostat located in one of the zones served by the system.

The intent is that all major exposures be controlled by their own thermostat, and that the thermostat be located within the conditioned perimeter zone. Other temperature controls, such as outdoor temperature reset or solar compensated outdoor reset, do not meet the requirements of the *Standards*.

Example 4-11: Perimeter Systems Thermostats

Question

What is the perimeter zoning required for the building shown here?



Answer

The southeast and northwest exposures must each have at least one perimeter system control zone, since they are more than 50 feet in length. The southwest exposure and the serrated east exposure do not face one direction for more than 50 continuous feet in length. They are therefore "minor" exposures and need not be served by separate perimeter system zones, but may be served from either of the adjacent zones.

Shut-off and Temperature Setup/Setback (§122(e))

For specific occupancies and conditions, each space-conditioning system must be provided with controls that can automatically shut off the equipment during unoccupied hours. The control device can be either:

1. An *automatic time switch* device must have the same characteristics that lighting devices must have, as described in Section 5.2.1. This can be accomplished with a seven day programmable thermostat with a battery backup of at least ten hours.

   A manual override accessible to the occupants must be included in the control system design either as a part of the control device, or as a separate override control. This override shall allow the system to operate up to four hours during normally unoccupied periods.

2. An *occupancy sensor*. Since a building ventilation purge is required prior to normal occupancy (Section 121(c)2), an occupancy sensor may be used to control the availability of heating and cooling, but should not be used to control the outdoor ventilation system (unless the building is intermittently occupied). In such a case, an automatic time switch should be used instead.

   When an automatic time switch is used to control ventilation while occupancy sensors are used simultaneously to control heating and cooling, the controls should be interlocked so that ventilation can be provided during off-hours operation.

3. A *four-hour timer* that can be manually operated to start the system. As with occupancy sensors, the same restrictions apply to controlling outdoor air ventilation systems.

When shut down, the controls shall automatically restart the system to maintain:

1. A **setback heating thermostat setpoint**, if the system provides mechanical heating. Thermostat setback controls are not required in areas where the Winter Median of Extremes outdoor air temperature is greater than 32°F (Section 122(e)2.A and Exception).

2. A **setup cooling thermostat setpoint**, if the system provides mechanical cooling. Thermostat setup controls are not required in areas where the Summer Design Dry Bulb 0.5 percent temperature is less than 100°F Section 122(e)2.B and Exception).

Example 4-12: Office Occupancy Sensor

Question

Can occupancy sensors be used in an office to shut off the VAV boxes during periods the spaces are unoccupied?

Answer
Not completely. The occupancy sensor could be used to reduce the VAV box airflow to the minimum allowed for ventilation. It should not shut the airflow off completely, because Section 121(c) requires that ventilation be supplied to each space at all times when the space is usually occupied.

Example 4-13: Automatic Time Switches with Multiple Systems

Question

Must a 48,000 square foot building with 35 fan coil units have 35 time switches?

Answer

No. More than one space-conditioning system may be grouped on a single time switch, subject to the area limitations required by the isolation requirements (see Isolation). In this case, the building would need two isolation zones, each no larger than 25,000 square feet, and each having its own time switch.

Example 4-14: Thermostat with Sensors

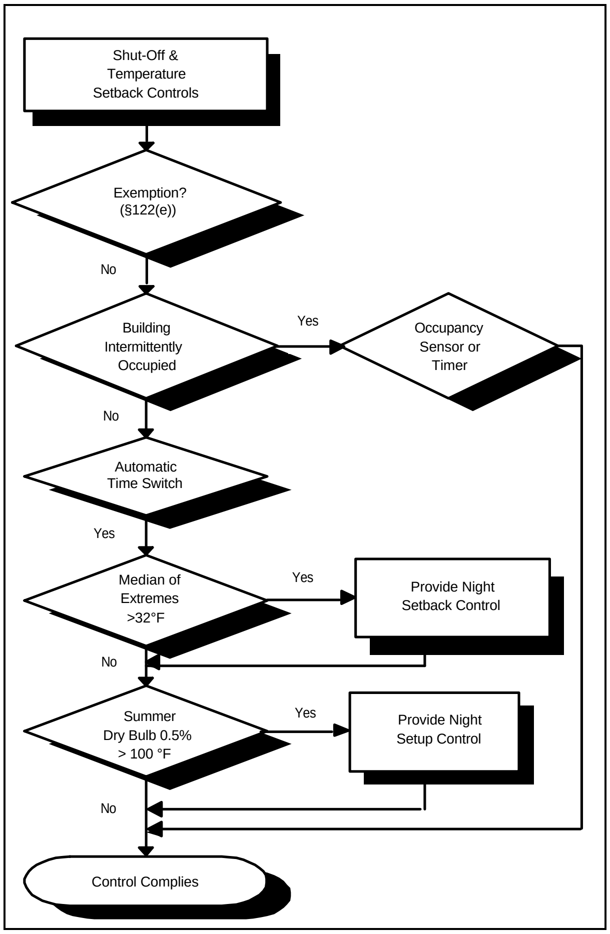
Question

Can a thermostat with setpoints determined by sensors (such as a bi-metal sensor encased in a bulb) be used to accomplish a night setback?

Answer

Yes. The thermostat must have two heating sensors, one each for the occupied and unoccupied temperatures. The controls must allow the setback sensor to override the system shutdown.

Figure 4-7: Shut-Off and Setback Controls Flowchart



These provisions are required by the *Standards* to reduce the likelihood that shut-off controls will be circumvented to cause equipment to operate continuously during unoccupied hours.

Automatic shut-off, setback and setup devices are not required where:

1. It can be demonstrated to the satisfaction of the enforcement agency that the system serves an area that must operate continuously (Section 122(e) Exception No. 1); or

2. It can be demonstrated to the satisfaction of the enforcement agency that shutdown, setback, and setup will not result in a decrease in overall building source energy use (Section 122(e) Exception No. 2); or

3. *Systems* have a full load demand less than 2 kW, or 6,828 Btu/hr, if they have a readily accessible manual shut-off switch (Section 122(e) Exception No. 3). Included is the energy consumed within all associated space-conditioning systems including compressors, as well as the energy consumed by any boilers or chillers that are part of the system.

4. Systems serve hotel/motel guest rooms, if they have a readily accessible manual shut-off switch Section 122(e) Exception No.4).

5. The mechanical system serves retail stores and associated malls, restaurants, grocery stores, churches, or theaters equipped with a 7 day programmable timer.

Example 4-15: Time Control for Fan Coils

Question

If a building has a system comprised of 30 fan coil units, each with a 300 watt fan, a 500,000 Btu/hr boiler, and a 30-ton chiller, can an automatic time switch be used to control only the boiler and chiller (fan coils operate continuously)?

Answer

No. The 2 kW criteria applies to the system as a whole, and is not applied to each component independently. While each fan coil only draws 300 watts, they are served by a boiler and chiller that draw much more. The consumption for the system is well in excess of 2 kW.

Assuming the units serve a total area of less than 25,000 square feet (see Isolation), one time switch may control the entire system.

Dampers (§122(f))

Outdoor air supply and exhaust equipment must incorporate dampers that automatically close when fans shut down. The dampers may either be motorized, or of the gravity type.

Damper control is not required where it can be demonstrated to the satisfaction of the enforcement agency that the space-conditioning system must operate continuously (Exception No. 1). Nor is damper control required on gravity ventilators or other non-electrical equipment, provided that readily accessible manual controls are incorporated (Exception No. 2).

Damper control is also not required at combustion air intakes and shaft vents, or where prohibited by other provisions of law (Exceptions No. 3 and 4). If the designer elects to install dampers or shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in a fire in accordance with applicable fire codes.

Isolation Area Devices (§122(g))

Large space-conditioning systems serving multiple zones may waste considerable quantities of energy by conditioning all zones when only a few zones are occupied. Typically, this occurs during evenings or weekends when only a few people are working. When the total area served by a system exceeds 25,000 square feet, the *Standards* require that the system be designed, installed and controlled with area isolation devices to minimize energy consumption during these times. The requirements are:

1. The building shall be divided into isolation areas, the area of each not exceeding 25,000 square feet. An isolation area may consist of one or more *zones*.

2. Each isolation area shall be provided with isolations devices such as valves or dampers, that allow the supply of heating or cooling to be setback or shut off independently of other isolation areas.

3. Each isolation area shall be controlled with an automatic time switch, occupancy sensor, or manual timer. The requirements for these shut-off devices are the same as described previously in Section 122(e)1. As discussed previously for occupancy sensors, a building purge must be incorporated into the control sequences for normally occupied spaces, so occupancy sensors and manual timers are best limited

to use in those areas that are intermittently occupied.

Any zones requiring continuous operation do not have to be included in an isolation area.

Example 4-16: Isolation Zones

Question
How many isolation zones does a 55,000 sf building require?
Answer
At least three. Each isolation zone may not exceed 25,000 square feet.

Isolation of Zonal Systems

Small zonal type systems such as water loop heat pumps or fan coils may be grouped on automatic time switch devices, with control interlocks that start the central plant equipment whenever any isolation area is occupied. The isolation requirements apply to equipment supplying heating and cooling only; central ventilation systems serving zonal type systems do not require these devices.

Isolation of Central Air Systems

Central air handling stations may incorporate supply and return dampers on a floor-by-floor or other basis, provided the total area of each isolation zone does not exceed 25,000 square feet. Smoke/fire dampers required by other codes may be used for this purpose if approved by the fire authority having jurisdiction. The system does not require isolation on the return air side.

VAV boxes may be controlled to shut-off directly, eliminating the need for dampers in the supply.

Example 4-17: Isolation Zone Purge

Question
Does each isolation zone require a ventilation purge?
Answer
Yes.

Isolation of Central Plants

The *Standards* do not require any isolation of central plant equipment. It is recommended that the number and type of boilers, chillers, pumps, and other central equipment be chosen so that the plant efficiency at part load is equal to or greater than the efficiency at full load. Since space-conditioning systems seldom operate at peak conditions, this approach will reduce energy consumption during times of normal occupancy, in addition to off-hours.

Interference with Fire and Life Safety

Isolation devices should not interfere with the function of any fire and life safety systems. For example, if an isolation damper is located in the same duct or opening as a smoke/fire damper controllable from the fire panel, the isolation damper should be interlocked to open in a fire situation so as not to interfere with the operation of the smoke/fire damper. The same is true for VAV boxes if they are used for isolation purposes.

I. Requirements for Pipe Insulation (§123)

Most piping conveying either mechanically heated or chilled fluids for space conditioning or service water heating must be insulated in accordance with Section 123. The required thickness of piping insulation depends on the temperature of the fluid passing through the pipe, the pipe diameter, the function of the pipe within the system, and the insulation's thermal conductivity. Table 4-3 (Table No. 1-G in the *Standards*) specifies the requirements in terms of inches of fiberglass or foam pipe insulation. In this table, runouts are defined as being less than two-inches in diameter, less than 12 feet long, and connected to fixtures or individual terminal units.

Piping that does not require insulation includes the following:

1. Factory installed piping within certified space-conditioning equipment.

2. Piping that conveys fluid with a design operating temperature range between 60°F and 105°F, such as cooling tower piping or piping in water loop heat pump systems.

3. Piping that serves process loads, gas piping, cold domestic water piping, condensate drains, roof drains, vents or waste piping.

> Note:
>
> Designers may specify exempt piping conveying cold fluids to be insulated in order to control condensation on the surface of the pipe. Examples may include cold domestic water piping, condensate drains and roof drains. In these cases, the insulation R-value is specified by the designer and is not subject to these regulations.

4. Where the heat gain or heat loss, to or from piping without insulation, will not increase building source energy use. For example, piping connecting fin-tube radiators within the same space would be exempt.

   This exception would not exempt piping in solar systems. Solar systems typically have backup devices that will operate more frequently if piping losses are not minimized.

Conductivities and thicknesses listed in Table 4-3 are typical for fiberglass and foam. When insulating materials are used that have conductivities different from those listed here for the applicable fluid range, such as calcium silicate, Equation 4-1 must be used to calculate the required insulation thickness.

When a pipe carries cold fluids, condensation of water vapor within the insulation material may impair the effectiveness of the insulation, particularly for applications in very humid environments or for fluid temperatures below 40°F. Examples include refrigerant suction piping and low-temperature thermal energy storage (TES) systems. In these cases, manufacturers should be consulted and consideration given to low permeability vapor barriers, or closed-cell foams.

Table 4-3: Pipe Insulation Thickness

Fluid Temperature Range	Conductivity Range (in Btu-inch per hour per sf. per degree F)	Insulation Mean Rating Temperature	Nominal Pipe Diameter (in inches) Runouts up to 2	1 and Less	1.25 - 2	2.50 - 4	5 - 6	8 and Larger
			Insulation Thickness Required (in inches)					
Space Heating Systems (Steam, Steam Condensate and Hot Water)								
Above 350	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5	3.5
251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5	3.5
201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0	3.5
141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5	1.5
105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5	1.5
Service Water Heating Systems (recirculating sections, all piping in electric trace tape systems, and the first 8 feet of piping from the storage tank for non-recirculating systems)								
Above 105	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
Space Cooling Systems (Chilled Water, Refrigerant, and Brine)								
40-60	0.23-0.27	75	0.5	0.5	0.5	1.0	1.0	1.0
Below 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

Equation 4-1: Insulation Thickness

$$T = PR[(1 + t/PR)^{K/k} - 1]$$

Where:

T = Minimum insulation thickness for material with conductivity K, inches.

PR = Pipe actual outside radius, inches.

t = Insulation thickness from Table 4-3, inches.

K = Conductivity of alternate material at the mean rating temperature indicated in Table 4-3 for the applicable fluid temperature range, in Btu-in/(hr-sf-°F).

k = The lower value of the conductivity range listed in Table 4-3 for the applicable fluid temperature, Btu-in/(hr-sf-°F).

Example 4-18: Pipe Insulation Thickness

Question

What is the required thickness for calcium silicate insulation on a 4 inch diameter pipe carrying a 300°F fluid?

Answer

From Table 4-3, the required insulation thickness is 2.5 inches for a 4 inch pipe in the range of 251-350°F. The mean conductivity at this temperature is listed as 0.29 (Btu-in) / (hr-sf-°F). From manufacturer's data, it is determined that the conductivity of calcium silicate at 300°F is 0.45 Btu-in/(hr-sf-°F). The required thickness is therefore:

$$T = PR[(1 + t/PR)^{K/k} - 1]$$

$$T = 4''[(1 + 2.5/4)^{0.45/0.29} - 1]$$

$$T = 4.3 \text{ inches}$$

When insulation is not available in the exact thickness calculated, the installed thickness should be the next larger available size.

J. Requirements for Air Distribution System Ducts and Plenums (§124)

Poorly sealed or poorly insulated duct work can cause substantial losses of air volume and energy. The 1998 amendments include more detailed requirements for constructing ducts and plenums. All air distribution system ducts and plenums, including building cavities, mechanical closets, air handler boxes and support platforms used as ducts or plenums, are required to be installed, sealed, and insulated in accordance with the 1997 Uniform Mechanical Code (UMC) Sections 601, 603, 604 and Standard 6-3.

Installation and Insulation (§124(a))

Ducts or plenums conveying conditioned air must either be insulated to R-4.2 (or any higher level required by UMC Section 604), or be enclosed entirely in conditioned space. UMC insulation requirements are reproduced in Table 4-4. The following are also required:

- Mechanically fasten connections between metal ducts and the inner core of flexible ducts.
- Seal openings with mastic, tape, aerosol sealant or other duct closure system that meets the applicable requirements of UL 181, UL 181A or UL 181B.
- When mastic or tape is used to seal openings greater than 1/4 inch, a combination of mastic and mesh or mastic and tape must be used.

Duct and Plenum Materials (§124(b))

Factory-Fabricated Duct Systems

Factory-fabricated duct systems must meet the following requirements:

- Duct and closure systems comply with UL 181, including collars, connections and splices, and must be UL labeled.
- Pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts comply with UL 181.
- Pressure-sensitive tapes and mastics used with flexible ducts comply with UL 181 or UL 181B.

Field-Fabricated Duct Systems

Field-fabricated duct systems must meet the following requirements:

- Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems comply with UL 181. Pressure-sensitive tapes, mastics, aerosol sealants or other closure systems must meet applicable requirements of UL 181, UL 181A or UL 181B.
- Mastic Sealants and Mesh.

  ‣ Sealants comply with UL 181, UL 181A, or UL 181B, and must be non-toxic and water resistant.

  ‣ Sealants for interior applications pass ASTM tests C 731(extrudability after aging) and D 2202 (slump test on vertical surfaces), incorporated herein by reference.

  ‣ Sealants for exterior applications shall pass ASTM tests C 731, C 732 (artificial weathering test) and D 2202, incorporated herein by reference.

  ‣ Sealants and meshes shall be rated for exterior use.
- Pressure-sensitive tapes comply with UL 181, UL 181A or UL 181B.
- Drawbands used with flexible duct shall:

- Be either stainless-steel worm-drive hose clamps or uv-resistant nylon duct ties.
- Have a minimum tensile strength rating of 150 pounds.
- Be tightened as recommended by the manufacturer with an adjustable tensioning tool.

- Aerosol-Sealant Closures.
  - Aerosol sealants meet applicable requirements of UL 181, 181A or 181B and must be applied according to manufacturer specifications.
  - Tapes or mastics used in combination with aerosol sealing must meet the requirements of this section.

Example 4-19: Duct Sealing

Question

What are the sealing requirements in a VAV system having a static pressure setpoint of 1.25" w.g. and a plenum return?

Answer

All duct work located within the return plenum must be sealed in accordance with the UMC Section 601,603,604. Pressure-sensitive tape, heat-seal tape and mastic may be used, if it meets the applicable requirement of UL 181, 181A, 181B, to seal joints and seams which are mechanically fastened per the UMC.

K. Service Water Systems (§113)

Efficiency and Controls (§113(a))

Any service water heating system or equipment may be installed only if the manufacturer has certified that the equipment meets or exceeds the efficiency requirements listed in Appendix B, Table B-9. The equipment must also have integral automatic temperature controls that allow the temperature to be adjusted from the lowest to the highest allowed temperature settings for the intended use as listed in Table 3, Chapter 45 of the 1995 *ASHRAE Handbook, HVAC Applications Volume*.

Service water heaters installed in residential occupancies need not meet the control requirement.

Table 4-4: Duct Insulation Requirements

DUCT LOCATION [1]	INSULATION R-VALUE MECHANICALLY COOLED	HEATING ZONE	INSULATION R-VALUE HEATING ONLY
On roof on exterior building	6.3	< 4,500 DD	2.1
		< 8,000 DD	4.2
Attics, garages, and crawl spaces	2.1	< 4,500 DD	2.1
		< 8,000 DD	4.2
In walls [2] and within floor to ceiling spaces[2]	2.1	< 4,500 DD	2.1
		< 8,000 DD	4.2
Within the conditioned space or in basements; return ducts in air plenums	None Required		None Required
Cement slab or within ground	None Required		None Required

[1] Vapor barriers shall be installed on supply ducts in spaces vented to the outside in geographic areas where the average July, August and September mean dew point temperature exceeds 60 degrees Fahrenheit.

[2] Insulation may be omitted on that portion of a duct which is located within a wall or a floor to ceiling space where:

a. Both sides of the space are exposed to conditioned air.
b. The space is not ventilated.
c. The space is not used as a return plenum.
d. The space is not exposed to unconditioned air.

Ceilings which form plenums need not be insulated.

NOTE: Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

Source: Uniform Mechanical Code §604

Multiple Temperature Usage (§113(b)1)

On systems that have a total capacity greater than 167,000 Btu/hr, outlets requiring higher than service water temperatures as listed in the 1995 *ASHRAE Handbook, HVAC Applications Volume* shall have separate remote heaters, heat exchangers, or boosters to supply the outlet with the higher temperature. This requires the primary water heating system to supply water at the lowest temperature required by any of the demands served for service water heating. All other demands requiring higher temperatures should be served by separate systems, or by boosters that raise the temperature of the primary supply.

Circulating Systems (§113(b)2)

Circulating service water systems must include a control capable of automatically turning off the circulating pump when hot water is not required. Such controls include automatic time switches, interlocks with HVAC time switches, occupancy sensors, and other controls that accomplish the intended purpose. Since residential occupancies have different supply requirements they do not have to meet the requirements of Section 113(b)2.

Public Lavatories (§113(b)3)

Lavatories in public restrooms must have controls that limit the water supply temperature to 110°F. Where a service water heater supplies only restrooms, the heater thermostat may be set to no greater than 110°F to satisfy this requirement; otherwise controls such as automatic mixing valves must be installed.

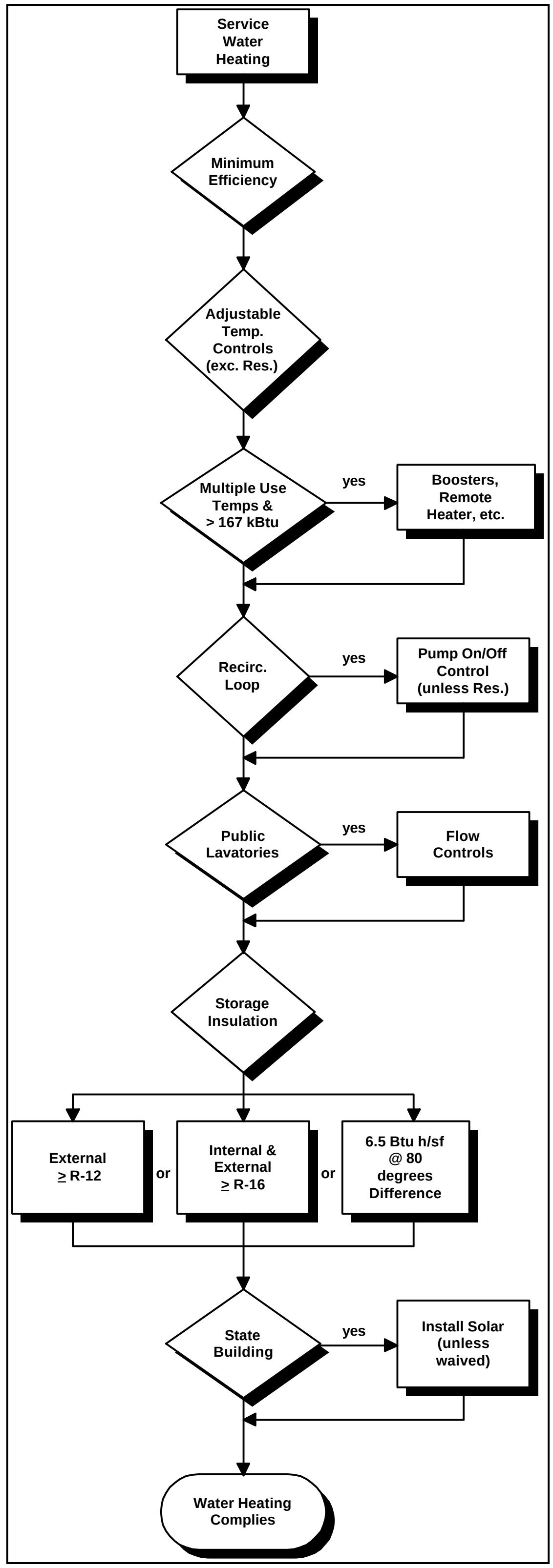
Storage Tank Insulation (§113(b)4)

Unfired water heater storage tanks and backup tanks for solar water heating systems must have:

1. **External insulation** with an installed R-value of at least R-12; or

2. **Internal and external insulation** with a combined R-value of at least R-16; or

Figure 4-8: Service Water Heating Flowchart



3. The **heat loss** of the tank based on an 80 degree F water-air temperature difference shall be less than 6.5 Btu per hour per square foot. This corresponds to an effective resistance of R-12.3.

Service Water Heaters in State Buildings (§113(b)5)

Any new building constructed by the State shall derive its service water heating from a system that provides at least 60 percent of the energy needed from site solar energy or recovered energy. This requirement may be waived for buildings where the State Architect determines that such systems are economically or physically infeasible.

L. Pool and Spa Heating Systems (§114)

Pool and spa heating systems must be certified by the manufacturer and listed by the Energy Commission as having:

1. An **efficiency** of at least 78 percent when tested according to ANSI Standard Z21.56-1994; and

2. An **on-off switch** mounted on the outside of the heater in a readily accessible location that allows the heater to be shut-off without adjusting the thermostat setting; and

3. A permanent, easily readable, and weatherproof plate or card that gives **instructions** for the energy efficient operation of the pool or spa, and for the proper care of the pool or spa water when a cover is used; and

4. No **electric resistance heating**. The only exceptions are:

   a. *Packaged listed units* with fully insulated enclosures and tight fitting covers that are insulated to at least R-6. Package listed units are defined in the *National Electric Code* and are typically sold as self-contained, UL Listed spas; or

   b. Pools or spas deriving at least 60 percent of the annual heating energy from site solar energy or recovered energy.

5. **No pilot light.**

Pool and spa equipment must be installed with all of the following:

1. **Solar heater connection** - At least 36 inches of pipe between the filter and the heater must be provided to allow for the future addition of solar heating equipment.

2. A **cover** must be provided for outdoor pools and outdoor spas, unless at least 60 percent of the annual heating energy is provided by site solar energy or recovered energy.

3. **Directional inlets** must be provided for all pools that adequately mix the pool water.

4. A **time switch** must be provided for pools to control the operation of the circulation pump, to allow the pump to be set to run in the off-peak demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

   A time switch is not required where applicable public health standards require on-peak operation.

4.2.2 Prescriptive Approach

This section presents requirements that must be incorporated into the system design if the prescriptive path of compliance is used. Unlike mandatory requirements, however, these requirements may be traded off against other measures if the designer elects to use the performance path.

A. Sizing and Equipment Selection (§144(a))

The energy efficiency of many types of equipment can be lower at part load than at full load. The *Standards*, therefore, require that mechanical heating and cooling equipment (including electric heaters and boilers) be the smallest size available, within the available options of the desired equipment line, that meets the design heating and cooling loads of the building or spaces being served.

When equipment is offered in size increments, such that one size is too small and the next is too large, the larger size may be selected.

Packaged HVAC equipment may serve a space having substantially different heating and cooling loads. The unit size should be selected on the larger of the loads, based on either capacity or airflow. The capacity for the other load should be selected as required to meet the load, or if very small, should be the smallest capacity available in the selected unit. For example, packaged air-conditioning units with gas heat are usually sized on the basis of cooling loads. The furnace is sized on the basis of airflow, and is almost always larger than the design heating load.

Equipment may be oversized provided one or more of the following conditions are met:

1. It can be demonstrated to the satisfaction of the enforcing agency that oversizing will not increase building source energy use; or

2. Oversizing is the result of standby equipment that will operate only when the primary equipment is not operating. Controls must be provided that prevent the standby equipment from operating simultaneously with the primary equipment; or

3. Multiple units of the same equipment type are used, each having a capacity less than the design load, but in combination having a capacity greater than the design load. Controls must be provided to sequence or otherwise optimally control the operation of each unit based on load.

B. Load Calculations (§144(b))

For the purposes of sizing HVAC equipment, the designer shall use all of the following criteria for load calculations:

1. The heating and cooling system **design loads** must be calculated in accordance with the procedures described in the *ASHRAE Handbook, 1993, Fundamentals Volume*. Other load calculation methods, e.g. ACCA, SMACNA, *etc.* are acceptable provided that the method is ASHRAE-based. When submitting load calculations of this type, the designer must accompany the load calculations with a written affidavit certifying that the method used is ASHRAE-based. If the designer is unclear as to whether or not the calculation method is ASHRAE-based, the vendor or organization providing the calculation method should be contacted to verify that the method is derived from ASHRAE.

Example 4-20: Equipment Sizing

Question

Do the sizing requirements restrict the size of duct work, coils, filter banks, etc. in a built-up system?

Answer

The intent of the Standards is to limit the size of equipment which, if oversized, will consume more energy on an annual basis. Coils with larger face areas will usually have lower pressure drops than otherwise, and may also allow the chilled water temperature to be higher, both of which may result in a decrease in energy usage. Larger filter banks will also usually save energy. Larger duct work will have lower static pressure losses which may save energy, depending on the duct's location, length, and degree of insulation. An oversized airfoil fan with inlet vanes will not usually save energy, as the part load characteristics of this device are poor. The same fan with a variable frequency drive may save energy. Controls are also an important part of any system design.

The relationship between various energy consuming components may be complex, and is left to the designer's professional judgment. Note however, that when components are oversized, it must be demonstrated to the satisfaction of the enforcement agency that energy usage will not increase.

2. **Indoor design conditions** of temperature and relative humidity for general comfort applications are not explicitly defined. Designers are allowed to use any temperature conditions within the "comfort envelope" defined by ANSI/ASHRAE 55-1992 or Chapter 8 of the *ASHRAE Handbook, 1993, Fundamentals Volume*. Winter humidification or summer dehumidification is not required.

3. **Outdoor design conditions** shall be selected from ASHRAE Publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982 for the following design conditions:

   Heating design temperatures shall be no lower than the temperature listed in the Winter Median of Extremes column.

   Cooling design dry bulb temperatures shall be no greater than the temperature listed in the Summer Design Dry Bulb 0.5% column. The design wet bulb temperature shall be no greater than the temperature listed in the Summer Design Wet Bulb 0.5% column.

4. **Outdoor Air Ventilation** loads must be calculated using the ventilation rates required in Section 121. At minimum, the ventilation rate will be 15 cfm/person or 0.15 cfm/sf, whichever is greater.

5. **Envelope** heating and cooling loads must be calculated using envelope characteristics including square footage, thermal conductance, solar heat gain coefficient and air leakage, consistent with the proposed design.

5. **Lighting** loads shall be based on actual design lighting levels or power densities consistent with Section 146.

7. **People** sensible and latent gains must be based on the expected occupant density of the building and occupant activities. If ventilation requirements are based on a cfm/person basis, then people loads must be based on the same number of people as ventilation. Sensible and latent gains must be selected for the expected activities as listed in *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 26, Table 3.

8. **Loads** caused by a process shall be based on actual information (not speculative) on the intended use of the building.

9. **Miscellaneous equipment loads** include such things as duct losses, process loads and infiltration and shall be calculated using design data compiled from one or more of the following sources:

   a. **Actual information** based on the intended use of the building; or

   b. Published data from manufacturer's technical publications and from technical societies, such as the ASHRAE Handbook, 1995 HVAC Applications Volume; or

   c. Other data based on the designer's experience of expected loads and occupancy patterns.

10. **Internal heat gains** may be ignored for heating load calculations.

11. A **safety factor** of up to 10 percent may be applied to design loads to account for unexpected loads or changes in space usage.

12. **Other loads** such as warm-up or cool-down shall be calculated using one of the following methods:

    a. A method using principles based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time; or

    b. The steady state design loads may be increased by no more than 30 percent for heating and 10 percent for cooling.

The steady state load may include a safety factor of up to 10 percent as discussed above in Item 11.

The combination of safety factor and other loads allows design cooling loads to be increased by up to 21 percent (1.10 safety x 1.10 other), and heating loads by up to 43 percent (1.10 safety x 1.30 other).

C. *Fan Power Consumption (§144(c))*

Maximum fan power is regulated in individual fan systems where the total power index of the supply, return and exhaust fans within the *fan system* exceed 25 horsepower at design conditions (see Section 4.1.2 for definitions). A system consists of only the components that must function together to deliver air to a given area; fans that can operate independently of each other comprise separate systems. Included are all fans associated with moving air from a given space-conditioning *system* to the conditioned spaces and back to the source, or to exhaust it to the outdoors.

The 25 horsepower total criteria apply to:

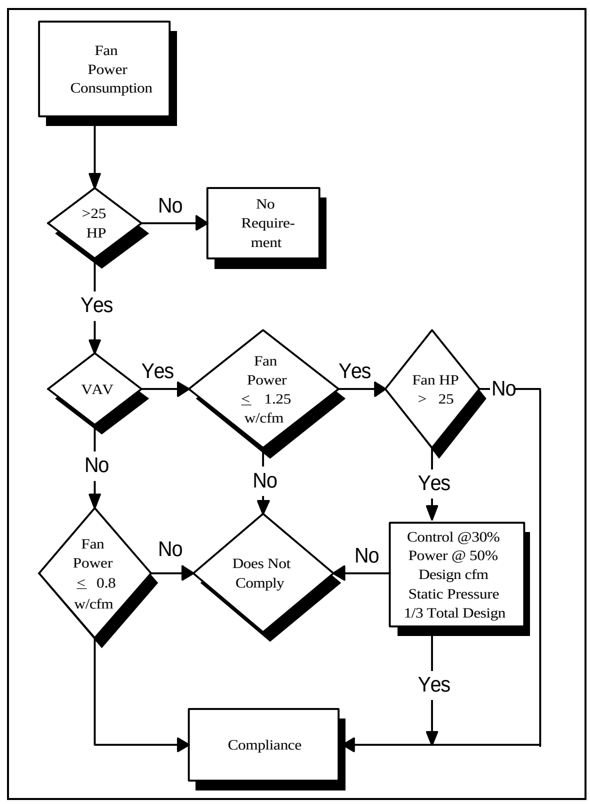
1. All **supply and return fans** within the space-conditioning system that operate at peak load conditions.
2. All **exhaust fans at the system level** that operate at peak load conditions. Exhaust fans associated with economizers are not counted provided they do not operate at peak conditions.
3. **Fan-powered VAV boxes**, if these fans run during the cooling peak. This is always the case for fans in series type boxes. Fans in parallel boxes may be ignored if they are controlled to operate only when zone heating is required, and are normally off during the cooling peak.
4. **Elevator equipment room exhausts**, or other exhausts that draw air from a conditioned space, through an otherwise unconditioned space, to the outdoors.
5. **Computer** room units.

   The criteria are applied individually to each space-conditioning system. In buildings having multiple space-conditioning systems, the criteria applies only to the systems having fans whose total demand exceeds 25 horsepower.

   Not included are fans not directly associated with moving conditioned air to or from the space-conditioning system, or fans associated with a process within the building.

For the purposes of the 25 horsepower criteria, horsepower is the brake horsepower as listed by the manufacturer for the design conditions, plus any losses associated with the drive, including belt losses or variable frequency drive losses. If the brake horsepower is not known, then the nameplate horsepower should be used.

Figure 4-9: Fan Power Consumption Flowchart



Example 4-21: 25 HP Limit

Question

If a building has five zones with 15,000 cfm air handlers that are served by a common central plant, and each air handler has a 15 HP supply fan, does the 25 HP limit apply?

Answer

No. Each air handler, while served by a common central plant, is considered a separate space-conditioning system. Since the demand of each air handler is only 15 HP, the 25 HP criteria does not apply.

If drive losses are not known, the designer may assume that direct drive efficiencies are 1.0, and belt drives are 0.97. Variable speed drive efficiency should be taken from the manufacturer's literature; if it includes a belt drive, it should be multiplied by 0.97.

Total fan horsepower need not include the additional power demand caused solely by air treatment or filtering systems with final pressure drops of more than 1 inch water gauge (w.g.). It is assumed that conventional systems may have filter pressure drops as high as 1 inch w.g.; therefore only the horsepower associated with the portion of the pressure drop exceeding 1 inch, or fan system power caused solely by process loads, may be excluded.

For buildings whose systems exceed the 25 horsepower criteria, the total space-conditioning system power requirements are:

Example 4-22: Filtration

Question

The space-conditioning system in a laboratory has a 30 percent filter with a design pressure drop at change out of 0.5 inch w.g., and an 80 percent filter with a design pressure drop of 1.2 inch w.g. The design total static pressure of the fan is 5.0 inchw.g. What percentage of the power may be excluded from the Watts/cfm calculation?

Answer

The total filter drop at change out (final pressure drop) is 0.5 inch + 1.2 inch = 1.7 inch w.g. The amount that may be excluded is 1.7 inch-1.0 inch = 0.7 inch w.g. The percentage of the horsepower that may be excluded is

0.7"/5.0" = 14%

If the supply fan requires 45 brake horsepower, the adjusted horsepower of the supply fan in the Watts/cfm calculation is

45 BHP x (1 - 14%) = 38.7 BHP

The horsepower of any associated return or exhaust fan is not adjusted by this factor, as the filters have no impact on these fans.

1. ***Constant volume*** space-conditioning systems shall not exceed 0.8 watts per cfm of supply air.

2. ***Variable Air Volume (VAV)*** systems shall not exceed 1.25 Watts per cfm of supply air at design conditions.

   In addition, individual VAV fans with motors over 25 horsepower shall meet three requirements: 1) a mechanical or electrical variable speed drive fan motor; 2) vane axial fan with variable pitch blades; and 3) include controls that limit the fan motor demand to no more than 30 percent of design wattage at 50 percent design air volume.

   Actual fan part load performance, available from the fan manufacturer, should be used to test for compliance with item 3) above. Figure 4-10 shows typical performance curves for different types of fans. As can be seen, both airfoil fans and backward inclined fans using either discharge dampers or inlet vanes consume more than 30 percent power at 50 percent flow when static pressure set point is one-third of total design static pressure using certified manufacturer's test data. These fans will not normally comply with these requirements unless a variable speed drive is used.

The total system power demand is based on brake horsepower at design static and cfm, and includes drive losses and motor efficiency. If the motor efficiency is not known, values from Appendix B, Table B-8A & 8B, may be assumed.

The power demand is calculated on a system by system basis, and the maximum limit applies to each system individually. In other words, the power demands of separate systems cannot be averaged.

Example 4-23: VAV Bypass System

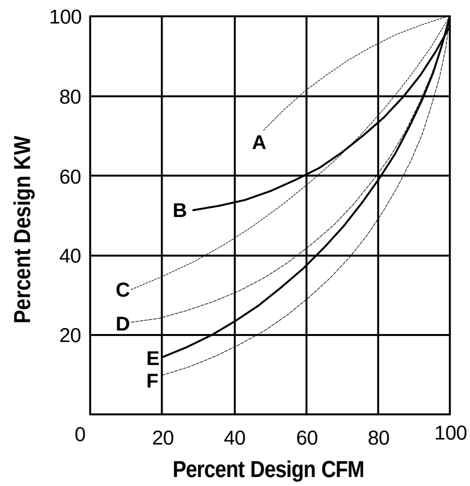
Question

What is the maximum allowed power consumption for the fans in a VAV bypass system?

Answer

A VAV bypass, while variable volume at the zone level, is constant volume at the fan level. If the total fan power demand of this system exceeds 25 HP, then the fan power may not exceed 0.8 Watts/cfm.

Figure 4-10: VAV Fan Performance Curve



A. Air foil or backward inclined centrifugal fan with discharge dampers
B. Air foil centrifugal fan with inlet vanes
C. Forward curved centrifugal fan with discharge dampers or riding curve
D. Forward curved centrifugal fan with inlet vanes
E. Vane-axial fan with variable pitch blades
F. Any fan with variable speed drive (mechanical drives will be slightly less efficient)

Example 4-24: Calculation of Fan Power

Question

What is the power consumption of a 20,000 cfm VAV system having an 18 BHP supply fan, a 5 BHP return fan, a 3 BHP economizer relief fan, a 2 HP outside air ventilation fan and a 1 HP toilet exhaust fan? Note that the exhaust and outside air ventilation fans are direct drive and listed in HP not BHP. The supply and return fans are controlled with variable frequency drives having an efficiency of 96 percent.

Answer

The economizer fan is excluded provided it does not run at the time of the cooling peak.

Power consumption is then based on the supply, return, outdoor and toilet exhaust fans. The ventilation fan is direct drive so its efficiency is 1.0. The supply and return fans have default drive efficiencies of 0.97. From Table B-8A & 8B, the assumed efficiencies of the motors are 88 percent and 85 percent for a 25 and 7.5 HP motor respectively. Fan power demand in units of horsepower must first be calculated to determine whether the requirements apply:

a. 18 BHP / (0.97 x 0.88 x 0.96) = 22.0 HP

b. 5 BHP / (0.97 x 0.85 x 0.96) = 6.3 HP

Total power consumption, adjusted for efficiencies, is calculated as:

22.0 HP + 6.3 HP + 2 HP + 1 HP = 31.3 HP

Since this is larger than 25 HP, the limitations apply. Watts per cfm is calculated as:

31.3 HP x 746 Watts/cfm/20,000 cfm = 1.17 Watts/cfm

The system complies because power consumption is below 1.25 Watts per cfm. Note that, while this system has variable frequency drives, they are not required by the Standards since each fan is less than 25 HP.

D. Space Conditioning Zone Controls (§144(d))

Each space-conditioning zone shall have controls that prevent:

1. **Reheating** of air that has been previously cooled by mechanical cooling equipment or an economizer.

2. **Recooling** of air that has been previously heated. This does not apply to air returned from heated spaces.

3. **Simultaneous heating and cooling** in the same zone, such as mixing or simultaneous supply of air that has been previously mechanically heated and air that has been previously cooled, either by cooling equipment or by economizer systems.

These requirements do not apply to zones having:

1. **VAV controls**, as discussed in Section E. below;

2. **Special pressurization relationships** or cross contamination control needs. Laboratories are an example of spaces that might fall in this category.

3. **Site-recovered or site-solar** energy providing at least 75 percent of the energy for reheating, or providing warm air in mixing systems.

4. **Specific humidity requirements** to satisfy process needs.

5. **300 cfm or less** peak supply air quantity. This exception allows reheating or recooling to be used in small zones served by constant volume systems.

Example 4-25: Minimum VAV CFM

Question

What is the required minimum cubic feet per minute (cfm) for a 1000 square foot office having a design supply of 1100 cfm and eight people?

Answer

Based on reheat requirements, the minimum cfm should not exceed the larger of:

a. 1000 sf x 0.4 cfm/sf = 400 cfm; or

b. 1100 cfm x 30% = 330 cfm; or

c. 300 cfm

Based on reheat, airflow must be reduced to no more than 400 cfm.

Outdoor ventilation requirements are the larger of:

a. 1000 sf x 0.15 cfm/sf = 150 cfm; or

b. 8 people x 15 cfm/person = 120 cfm

Based on ventilation requirements, the airflow must be at least 150 cfm. The minimum ventilation rate must then be in the range below the reheat requirement and above the ventilation requirement, or 150 – 400 cfm.

If, instead, the space were a conference room holding 35 people, then the design outdoor ventilation rate would be 35 x 15 = 525 cfm. Since this is above the reheat requirement of 400 cfm, the minimum cfm must be 525 cfm, unless transfer air is taken from other spaces

E. VAV Zone Controls (§144(d) Exception No. 1

Prior to reheating, recooling or mixing air, the controls in VAV zones must be set to reduce the air supply to a minimum. The minimum volume shall be no greater than the largest of:

1. 30 percent of the peak supply volume; or

2. 0.4 cfm per square foot of conditioned floor area of the zone; or

3. 300 cfm.

Note however, that Section 121(c) requires that the minimum rate of outdoor ventilation air calculated in Section 121(b)2 be supplied to each space at all times when the space is usually occupied. The allowable minimum airflow for a VAV box then usually falls in a range limited by the ventilation requirements at the lower end, and the reheat requirements at the upper end. In some cases, however, the required ventilation rate may be larger than the rate required for reheat. In this case, the required rate for reheat is the ventilation rate unless other provisions are made to supply ventilation air.

F. Economizers (§144(e))

An economizer must be fully integrated and must be provided for each individual cooling space-conditioning system that has a design supply capacity over 2,500 cfm and a total cooling capacity over 75,000 Btu/hr. The economizer may be either:

1. An ***air economizer*** capable of modulating outside air and return air dampers to supply 100 percent of the design supply air quantity as outside air. (For prescriptive compliance, samples of integrated economizers that meet this requirement are: fixed drybulb, differential drybulb, fixed enthalpy, or differential enthalpy); or

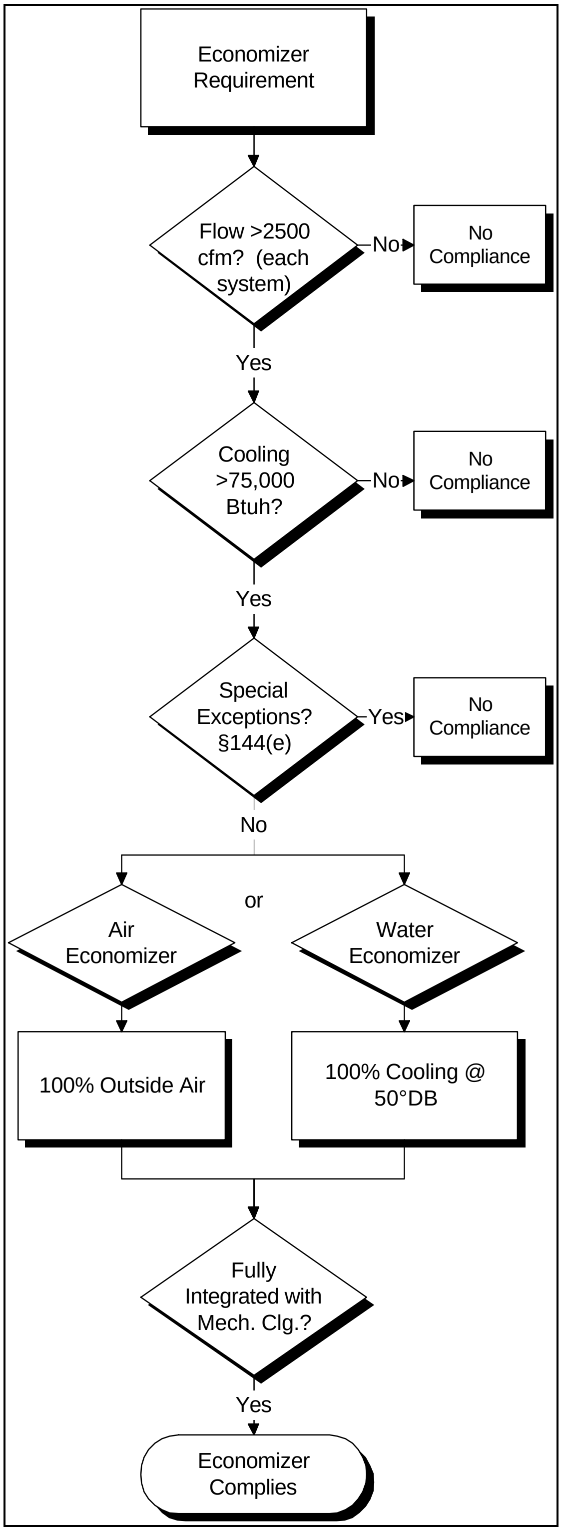
2. A ***water economizer*** capable of providing 100 percent of the expected system cooling load at outside air Figure temperatures of 50°F dry-bulb and 45°F wet-bulb and below. Economizers are not required where:

Economizers are not required where:

1. **Outside air filtration and treatment** for the reduction and treatment of unusual outdoor contaminants make compliance infeasible. This must be demonstrated to the satisfaction of the enforcement agency.

2. **Increased overall building energy use** results. This may occur where economizers adversely impact other systems, such as humidification, dehumidification or supermarket refrigeration systems.

Figure 4-11: Economizer Flowchart



3. Systems serving **high-rise residential living quarters** and **hotel/motel guest rooms**. Note that these buildings typically have systems smaller than 2,500 cfm, and also have provisions for natural ventilation.

4. If **cooling capacity** is less than or equal to 75,000 Btu/hr, or **supply airflow** is less than or equal to 2,500 cfm.

If an economizer is required, it must be designed and equipped with controls that do not increase the building heating energy use during normal operation. For example, when simultaneous cooling and zone reheat is required in a VAV system, the use of the economizer must not cause the supply air to be colder than it would be if the mechanical cooling were operating. The exception is when at least 75 percent of the annual heating is provided by site-recovered or site-solar energy (Section 144(e)2.A).

The economizer controls must also be fully *integrated* into the cooling system controls so that the economizer can provide partial cooling even when mechanical cooling is required to meet the remainder of the load Section 144(e)2.B).

The requirement that economizers be designed for concurrent operation is not met by some popular water economizer systems, such as those which use the chilled water system to convey evaporative-cooled condenser water for "free" cooling. Such systems can provide 100 percent of the cooling load, but when the point is reached where condenser water temperatures cannot be sufficiently cooled by evaporation, the system controls throw the entire load to the mechanical chillers. Because this design cannot allow simultaneous economizer and refrigeration system operation, it does not meet the requirements of this section.

Air economizers, water economizers and integrated controls are discussed in more detail in the Design Concepts section at the beginning of this Chapter.

G. Supply-Air Temperature Reset Control (§144(f))

Mechanical space-conditioning systems supplying heated or cooled air to multiple zones must include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls must be capable of resetting the supply-air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

For example, if the design supply temperature is 55°F and the design room temperature is 75°F, then the difference is 20°F, and 25 percent is 5°F. Therefore, the controls must be capable of resetting the supply temperature from 55°F to 60°F.

Air distribution zones that are likely to have constant loads, such as interior zones, shall have air flow rates designed to meet the load at the fully reset temperature. Otherwise, these zones may prevent the controls from fully resetting the temperature, or will unnecessarily limit the hours when the reset can be used.

Supply air reset is usually required for VAV reheat systems. It is also required for constant volume systems with reheat justified on the basis of special zone pressurization relationships or cross-contamination control needs.

Supply-air temperature reset is not required when:

1. The zone(s) must have specific humidity levels required to meet process needs; or

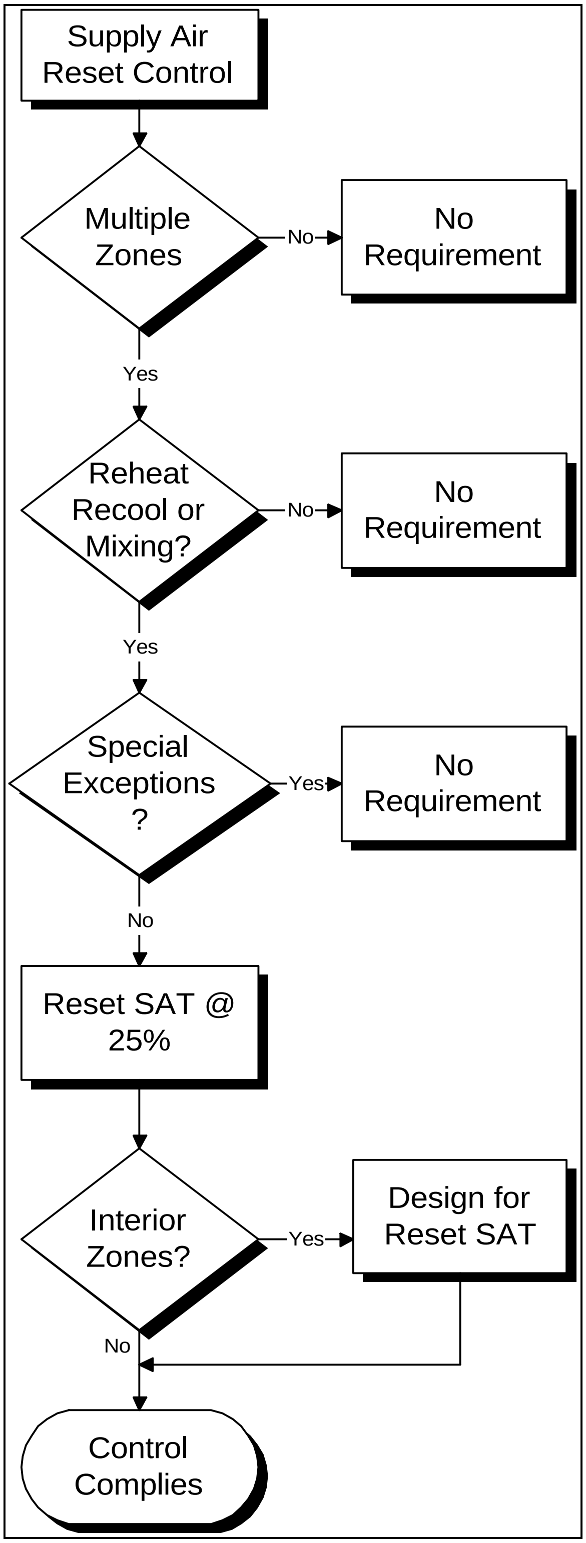
2. Where it can be demonstrated to the satisfaction of the enforcement agency that supply air reset would increase overall building energy use; or

3. The space-conditioning zone has controls that prevent reheating and recooling and simultaneously provide heating and cooling to the same zone; or

4. 75 percent of the energy for reheating is from *site-recovered* or *site solar* energy source; or

5. The zone has a peak supply air quantity of 300 cfm or less.

Figure 4-12: Supply Air Reset Controls Flowchart



H. Electric-Resistance Heating (§144(g))

The *Standards* strongly discourage the use of electric-resistance space heat. Electric-resistance space heat is not allowed in the prescriptive approach except where:

1. **Site-recovered** or **site-solar** energy provides at least 60 percent of the annual heating energy requirements; or

2. A **heat pump** is supplemented by an electric-resistance heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load at the design outdoor temperature, determined in accordance with these *Standards*; or

3. The **total capacity** of all electric-resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building; or

4. The total capacity of all electric-resistance heating systems serving the building, excluding those that supplement a heat pump, is **no more than 3 kW**; or

5. An electric-resistance heating system serves an entire building that:

    a. Is not a high-rise residential or hotel/motel building; and

    b. Has a conditioned floor area no greater than 5,000 square feet; and

    c. Has no mechanical cooling; and

    d. Is in an area where natural gas is not currently available and an extension of a natural gas system is impractical, as determined by the natural gas utility.

6. In alterations where the existing mechanical systems use electric reheat (when adding variable air volume boxes) added capacity cannot exceed 20 percent of the existing installed electric capacity, under any one permit application.

7. In an addition where the existing variable air volume system with electric reheat is being expanded the added capacity cannot exceed 50 percent of the existing installed electric reheat capacity under any one permit.

The *Standards* in effect allow a small amount of electric-resistance heat to be used for local space heating or reheating (provided reheat is in accordance with these regulations).

Example 4-26: Heat Pump Sizing

Question
If a heat pump is used to condition a building having a design heating load of 100,000 Btu/hr at 35°F, what are the sizing requirements for the compressor and heating coils?
Answer
The compressor must be sized to provide at least 75 percent of the heating load at the design heating conditions, or 75,000 Btu/hr at 35°F. The Standards do not address the size of the resistance heating coils. Normally, they will be sized based on heating requirements during defrost.

I. Service Water Heating (§145)

A service water-heating system is considered to comply with the prescriptive requirements when all mandatory requirements are met. The *Standards* for low-rise residential buildings have been adopted for service water-heating systems in high-rise residential buildings (see Appendix H).

4.2.3 Performance Approach

Under the performance approach, the energy use of the building is modeled using a computer program approved by the Energy Commission. This section presents some basic details on the modeling of building mechanical systems. *Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific Instructions on the operation of the program*. All computer programs, however, are required to have the same basic modeling capabilities.

The details of how to model the mechanical systems and components are included in Section 6.1. Specific application scenarios are contained in Section 6.1.4.

A. Compliance With a Computer Method

Each approved computer method automatically generates an *energy budget* by calculating the annual energy use of the standard design, a version of the proposed building incorporating all the prescriptive features.

A building complies with the *Standard* if the predicted source *energy use* of the proposed design is the same or less that the annual *energy budget* of the standard design. The energy budget includes a space-conditioning budget, lighting budget and water-heating budget.

Source energy use defines the energy use of a building by converting the calculated energy consumption into *source energy.* A table of *source energy multipliers* is found in Section 102*.* Source energy multipliers adjust the calculated energy consumption of a building to account for the energy content of different fuels and inefficiencies in generating and distributing electricity.

The budget for space conditioning of the proposed building design varies according to the following specific characteristics:

- Orientation
- Conditioned floor area
- Conditioned volume
- Gross exterior surface area
- Space-conditioning system type

- Occupancy type
- Climate zone

Assumptions used by the computer methods in generating the energy budget are explained in the *Alternative Calculation Methods Approval Manual* and are based on features required for prescriptive compliance.

B. Modeling Mechanical System Components

All alternative computer programs have the capability to model various types of HVAC systems. In central systems, these modeling features affect the system loads seen by the plant. This is done by calculating the interactions between envelope, mechanical and electrical systems in the building and summarizing the energy required by the mechanical system to maintain space conditions.

For a complete description of how to model mechanical system components, refer to the compliance supplement for the approved computer program being used to demonstrate compliance.

4.2.4 Alterations/Additions

When heating, cooling or service water heating are provided for an alteration or addition by expanding an existing system, that existing system need not comply with mandatory measures or compliance requirements. However, any altered component must meet all applicable mandatory measures.

When existing heating, cooling, or service water heating systems or components are moved within a building, the existing systems or components need not comply with mandatory measures nor with the prescriptive or performance compliance requirements.

4.2.5 Application to Major System Types

This section summarizes the Mandatory, Prescriptive, and Performance Measures as they apply to the major mechanical system designs as used in California. The systems presented are:

- Packaged air conditioner with gas furnace or heat pump
- Packaged VAV reheat
- Built-up VAV reheat
- Built-up single-fan dual duct VAV
- Built-up or packaged dual-fan dual-duct VAV
- Packaged terminal air conditioner with gas furnace or heat pump
- Four-pipe fan-coil system with central plant
- Hydronic heat pump with central plant

For each of these systems, the mandatory, prescriptive and performance measures are described. Limitations imposed by the *Standards*, if any, are discussed together with mitigating measures that can be taken.

Although there are more variations and combinations of systems than are covered here, this section can be used as a guide for other systems. Where there are ambiguities, the designer should refer directly to the Sections describing the Mandatory and Prescriptive requirements.

To avoid excessive redundancy, this section contains the requirements that normally apply to systems. There are various exceptions to these requirements that are not included here; the designer should refer to the sections detailing the mandatory, prescriptive and performance requirements for these exceptions.

In the following, mandatory requirements are designated by **[M]**, prescriptive by **[P]**, and performance by **[Pf]**.

A. Packaged Air Conditioner with Gas Furnace or Heat Pump

A packaged air conditioner with gas furnace is a self-contained system that uses a gas furnace to heat the supply air, and a direct expansion coil and compressor to cool the supply air. The package also includes a supply fan, condenser fan(s) and possibly return or exhaust fans. The compressor and outside air heat exchanger may be either integral to the unit, or remote.

Heating may alternatively be provided with a heat pump. In this case, controls and changeover valves are incorporated so that the compressor and heat exchangers can alternately provide heating or cooling. This system is commonly called a packaged heat pump.

The system is most commonly used in a single zone configuration, but subzone VAV configurations with or without reheat are also used. Where VAV zoning exists, VAV requirements also apply.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. Any equipment listed in Appendix B, Table B-9, shall comply with the **listed efficiencies** [M].

3. **Fan power consumption** must be no more than 0.8 Watts/cfm of supply air for constant volume systems (Section 4.2.2C [P]. The limit applies to the sum of the power of all supply, return, and exhaust fans in the space-conditioning system that operate during the peak design period, including toilet exhaust fans. This requirement does not apply to any fans that do not operate at peak, such as economizer exhaust fans. The limit does not apply to any space-conditioning system having fans totaling less than 25 HP.

4. **Ventilation** shall be in accordance with Section 4.2.1D - G [M]. For most office spaces, a minimum of 0.15 cfm/sf or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

5. A fully integrated **economizer** with controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F) [P]. The designer should refer to Section 4.2.2F for the exceptions.

6. **Electric-resistance heating** for reheat, etc. is prohibited in most circumstances (Section 4.2.2H) [P].

   When a heat pump is specified with supplementary resistance heaters, the heat pump capacity using only the compressor must be at least 75 percent of the design heating load at design conditions per Section 4.2.2H [P].

   The designer should refer to Section 4.2.2H for the exceptions.

7. **Zone Controls** shall be in accordance with Section 4.2.1H [M] and Section 4.2.2D and E [P].

   For single zone systems, a **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   Ventilation air must be provided at least 55 out of every 60 minutes (Section 4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to On.

For constant volume systems with subzones, the system must be designed and provided with controls to prevent **reheating** of cooled or economizer air [P]. Variable volume systems have different requirements described in Section 4.2.2E.

8. **System controls** shall be in accordance with Section 4.2.1H [M], and Section 4.2.2D and E [P]. The requirements are as follows:

   An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** (Section 4.2.1G)[M]. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes in not more than an hour, whichever is less.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

   If the system serves multiple zones, the controls must include a **supply air temperature reset** function per Section 4.2.2G[P].

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down.

   When a unit serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other per Section 4.2.1H[M]. Since most packaged units serve areas smaller than this, isolation can usually be accomplished by using automatic time switches for each unit or group of units.

9. **Heat pump thermostats and controls** must meet all of the requirements in items 7 and 8 above, and in addition must have controls [M]:

   a. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and

   b. In which the cut-on and cut-off temperatures for compression heating are higher than the temperatures for supplementary heating.

   The controls may allow supplementary heating during:

   a. Defrost; and

   b. Transient periods such as start-up or raising the room thermostat setpoint if the controls provide preferential rate control, intelligent recovery, staging, ramping or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

10. Ducts must be installed, sealed and insulated (Section 4.2.1J) [M] which follows UMC Sections 1002(b) and 1005.

B. Packaged VAV Reheat

A packaged variable air volume (VAV) system consists of a self-contained unit that uses a direct expansion coil and compressor(s) to cool the supply air, an optional heating section, and zones with individual VAV boxes. The package also includes a supply fan, condenser fan(s) and possibly return or exhaust fans. The compressor and condenser are normally integral to the system. The heating section may be either a gas furnace, a hot water coil, or a heat pump.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing**

must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. Any equipment listed in Table B-9 of Appendix B shall comply with the **listed efficiencies** [M].

3. **Design fan power consumption** must be no more than 1.25 Watts/cfm of supply air (Section 4.2.2C)[P]. The limit applies to the sum of the power of all supply, return, and exhaust fans in the space-conditioning system that operates during the peak design period, including toilet exhaust fans. This requirement does not apply to any fans that do not operate at peak, such as economizer exhaust fans. The limit does not apply to any system having fans totaling less than 25 horsepower (HP).

   If the system has fan-powered VAV boxes, the VAV box fan power is included if these fans run during the cooling peak.

   a. **Series box fans** must run continuously during occupied hours, so fan power is always included. If the box is sized to move more than the primary design supply quantity (induction ratio greater than 1.0), then the amount of additional plenum air supplied may be added to the total system supply cfm. Otherwise, the supply cfm is determined solely on the basis of the main supply fan.

Example 4-27: Series Fan-Powered Box

Question

How is the contribution to system fan power calculated for a series fan-powered VAV box having a primary air supply of 1,000 cfm, a total fan supply of 1,200 cfm, and a 450 watt fan?

Answer

Supply cfm cannot be double-counted. Since 1,000 cfm is being supplied by the main system fans, 1,200-1,000 = 200 cfm is contributed by the box fan, and may be added to the total system cfm.

Total system fan power is increased by 450 watts.

   b. **Parallel box fans** may or may not run continuously, depending on the designer's intent. If the fan runs only during periods of zone heating, then box cfm and power are excluded. If the fan runs continuously, then both fan airflow and power are taken into account.

Example 4-28: Parallel Fan-Powered Box

Question

How is the contribution to system fan power calculated for a parallel fan-powered box having a primary air supply of 1,000 cfm, a parallel fan supply of 300 cfm and a 1/15 HP motor? The box is part of a cold air distribution system (45 °F pimary supply temperature), and runs continuously to temper the supply air.

Answer

Since the 300 cfm contributed by the parallel fan is in addition to the primarily supply, total system supply is increased by 300 cfm.

The efficiency of a 1/15 horsepower motor is approximately 48 percent (Table B-8) and the direct drive efficiency is 1.0. Fan power is therefore:

(1/15 HP x 746 W/HP) / 0.48 = 104 watts

which is added to the total system power.

If instead the fan were controlled to operate only during zone heating, then both cfm and power would be excluded from the system calculations.

4. **Operating fan power consumption** of individual fans with motors 25 horsepower and larger shall be limited to no more than 30 percent of the design wattage at 50 percent design air volume (Section 4.2.2C) when static pressure set point equals 1/3 of the total design static pressure, based on certified manufacturer's test data. Mechanisms and controls shall be provided for this purpose.

Normally, fans of this size are either of the airfoil or vane-axial design. Airfoil fans riding the curve, using discharge dampers, or inlet vanes will not normally comply. Vane-axial fans require variable pitch blades to comply. Alternatively, a variable frequency drive can be used with either type of fan. Other fans, such as variable scroll fans may comply; manufacturer's data must be consulted.

5. **Ventilation** shall be in accordance with Section 4.2.1D - E [M]. For most office spaces, a minimum of 0.15 cfm/sf or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   This quantity of outdoor air must be delivered at all times of occupancy; provisions must be incorporated in the system to maintain this constant ventilation rate as the supply airflow rate decreases in response to low cooling loads. Conference rooms or other spaces having dense but intermittent occupancy levels may require fan-powered VAV boxes, transfer fans or other mechanisms to accommodate their high ventilation requirements through the use of transfer air.

6. A fully integrated **economizer** with controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2E) [P]. The economizer must be controlled such that its use does not overcool the mixed air and cause heating energy or reheat energy to increase.

   Economizers are not required in systems serving high-rise residential living quarters and hotel/motel guest rooms.

7. **Electric resistance heating** for reheat, etc. is prohibited in most circumstances (Section 4.2.2H) [P]. If supply air heating/cooling is provided by a heat pump specified with supplementary resistance heaters, the heat pump capacity using only the compressor must be at least 75 percent of the design heating load at design conditions[P].

8. **VAV Zone Controls** shall be in accordance with Section 4.2.1G and H [M], and Section 4.2.2E [P].

   For each zone, a thermostat must be provided to control the supply of heating and cooling [M]. Heating and cooling setpoints must be individually adjustable. The heating setpoint must be adjustable down to 55°F or lower (if reheat is provided), and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints.

   If no reheat is used, then a single setpoint zone thermostat may be used.

   Prior to reheating, recooling or mixing air, the controls must reduce the air supply to a flow no greater than the largest of [M]:

   a. 30 percent of the peak supply volume; or

   b. 0.4 cfm per square foot of conditioned floor area of the zone; or

   c. 300 cfm

   In addition, the minimum supply airflow must be equal to at least the minimum amount required to meet the ventilation requirements [M], unless some other means is provided to ensure outdoor ventilation at all times. Normally, the required minimum airflow will fall in a range bounded at the lower end by the ventilation requirement, and at the higher end by the reheat requirement. If the ventilation requirement is larger than the reheat requirement, then the reheat requirement is the same as the ventilation requirement.

   The VAV box controls should be able to measure the airflow rate and control the supply so that at least the minimum supply airflow rate is maintained at all times [M]. For this reason, VAV controls should of the **pressure independent** type; pressure dependent controls do not measure flow, and therefore should not be used.

Zonal VAV controls that reduce the airflow below the minimum ventilation rate more than 5 out of every 60 minutes cannot be used. For this reason, systems that alternately provide heated and cooled air to different zones through the same duct work cannot be used unless provisions are made to maintain the minimum ventilation rates (Section 4.2.2G) [M].

9. **System controls** shall be in accordance with Section 4.2.1H [M], 4.2.2D [P], and 4.2.2E [P]. The requirements are as follows:

   An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A 4-hour manual override must be accessible to the occupants for off-hours operation.

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes in no more than an hour, whichever is less.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

   The controls must include a **supply air temperature reset** function per Section 4.2.2G [P]. Air flow rates to **interior zones** or other zones with relatively constant loads should be based on the fully reset temperature.

   When a unit serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down or set back independently of each other per Section 4.2.1H [M].

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down [M]. In addition, if ventilation air is provided through these dampers, the dampers must be controlled so that the minimum ventilation quantities are maintained during all times of occupancy [M]. The designer should refer to Section 4.2.1H for more information.

10. Systems using **heat pumps** for central heating must have controls [M]:

    a. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and

    b. In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.

       The controls may allow supplementary heating during:

       i. Defrost; and

       ii. Transient periods such as start-up if the controls provide preferential rate control, intelligent recovery, staging, ramping, or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

11. **Ducts** must be installed, sealed and insulated per Section 4.2.1J [M]. Ducts must be insulated in compliance with UMC Section 1005. Higher insulation levels are encouraged, particularly when duct runs are very long, or run through unconditioned spaces.

12. Piping for unit hot water coils or reheat coils must be insulated in accordance with Section 4.2.1I[M].

C. *Built-up VAV Reheat*

Built-up VAV systems are thermodynamically similar to package VAV systems. While a packaged system is usually delivered and installed as a unit on the roof, a built-up system consists of individual components that are delivered to the site separately and are assembled within mechanical rooms. Supply air in a built-up system is commonly conditioned using hot and chilled water coils, although DX coils may also be used. A central boiler/chiller plant provides the working fluids to one or more air handling systems.

Hybrids of built-up and packaged systems also exist. For example a packaged unit may use a hot water coil for heating, that in turn is supplied with fluid from a central boiler. A built-up system may use a packaged air handler consisting of a fan, hot and chilled water coils, a filter section, and a mixing box all in one unit.

Because packaged and built-up VAV systems are thermodynamically similar, most of the requirements are the same. The following are the additional requirements for built-up systems:

1. The e**fficiency** of boilers and chillers shall be in accordance with Table B-9 in Appendix B [M].

2. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing open, restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A).

D. *Built-up Single-fan Dual-duct VAV*

A single-fan, dual-duct VAV system consists of a blow-through fan whose discharge splits into a “hot deck” with a heating coil and a “cold deck” with a cooling coil. A pair of ducts delivers heated and cooled air to VAV mixing boxes in each zone. Each box modulates the flow of hot and cold air to its zone to maintain space temperature setpoint. The system will usually have an economizer, and return/exhaust fans may also be incorporated.

The original versions of this system were constant volume; heated and cooled air were proportionately mixed to maintain space temperature while the total volume of air delivered to the space remained constant. These constant-volume systems wasted large amounts of heating and cooling energy in the mixing process, and are effectively prohibited by the *Standards* with few exceptions.

The prescriptive *Standards* imply that dual-duct systems be variable-volume; cooling air must be reduced to a minimum before heating air is allowed to mix. In this configuration, a dual duct system may be more energy efficient than a VAV reheat because less heating energy is required. This is because, when the economizer is closed, part or all of the zone heating can be effectively accomplished using return air, allowing heating energy to be reduced or eliminated. When the economizer is heating energy increases, as the hot deck must heat cool mixed air rather than return air. During these times, heating energy usage is similar to a VAV reheat system.

As with VAV systems, hybrids of packaged and built-up dual duct systems exist. For example a packaged unit may use a hot water coil for heating, which in turn is supplied with fluid from a central boiler. A built-up system may use a packaged air handler consisting of a fan, hot and chilled water coils, a filter section and a mixing box all in one unit.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. The **efficiency** of boilers and chillers shall be in accordance with Appendix B, Table B-9 [M].

3. **Design fan power consumption** must be no more than 1.25 Watts/cfm of supply air(Section 4.2.2C) [P]. The limit applies to the sum of the power of all supply, return, and exhaust fans in the space-conditioning

system that operate during the peak design period, including toilet exhaust fans. This requirement does not apply to any fans that do not operate at peak, such as economizer exhaust fans. The limit does not apply to any system having fans totaling less than 25 horsepower.

4. **Operating fan power consumption** of individual fans with motors 25 horsepower and larger shall be limited to no more than 30 percent of the design wattage at 50 percent design air volume when static pressure set point equals 1/3 of the total design static pressure, based on certified manufacturer's test data (Section 4.2.2C) [P]. Mechanisms and controls shall be provided for this purpose.

   Normally, fans of this size are either of the airfoil or vane-axial design. Airfoil fans riding the curve, using discharge dampers, or inlet vanes, will not normally comply. Vane-axial fans require variable pitch blades to comply. Alternatively, a variable frequency drive can be used with either type of fan. Other fans, such as variable scroll fans may comply; manufacturer’s data must be consulted.

5. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A).

6. **Ventilation** shall be in accordance with Section 4.2.1D through G[M]. For most office spaces, a minimum of 0.15 cfm/sf or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   This quantity of outdoor air must be delivered at all times of occupancy; provisions must be incorporated in the system to maintain this constant ventilation rate as the supply airflow rate decreases in response to low cooling loads. The designer should refer to Section 4.2.1 for additional guidance.

   Conference rooms, or other spaces having dense but intermittent occupancy levels, may require fan-powered VAV boxes, transfer fans or other mechanisms to accommodate their high ventilation requirements through the use of transfer air.

7. A fully integrated **economizer** with controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F)[P]. The economizer must be controlled such that its use does not overcool the mixed air and cause hot deck heating energy to increase. To this effect, the mixed air setpoint must be reset on the basis of the warmest zone. In other words, the economizer should open to reduce the mixed air temperature only when a cooling load exists.

   Economizers are not required in systems serving high-rise residential living quarters and hotel/motel guest rooms.

8. **Electric resistance heating** for reheat, etc. is prohibited in most circumstances (Section 4.2.2H) [P].

9. **VAV Zone Controls** shall be in accordance with Section 4.2.1H [M] and Section 4.2.2D and E [P].

   For each zone, a **thermostat** must be provided to control the supply of heating and cooling [M].

   Heating and cooling setpoints must be individually adjustable. The heating setpoint must be adjustable down to 55°F or lower (if reheat is provided), and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints.

   Prior to reheating, recooling or mixing air, the controls must reduce the air supply to a flow no greater than the largest of [M]:

   a. 30 percent of the peak supply volume; or

b. 0.4 cfm per square foot of conditioned floor area of the zone; or

c. 300 cfm

In addition, the minimum supply airflow must be equal to at least the minimum amount required to meet the ventilation requirements [M], unless some other means is provided to ensure outdoor ventilation at all times. Normally, the required minimum airflow will fall in a range bounded at the lower end by the ventilation requirement, and at the higher end by the reheat requirement. If the ventilation requirement is larger than the reheat requirement, then the reheat requirement is the same as the ventilation requirement.

The VAV box controls must be able to measure the airflow rate and control the supply so that the minimum airflow rate is maintained at all times [M]. For this reason, VAV controls should be of the **pressure independent** type; pressure dependent controls do not measure flow, and therefore cannot be used.

10. **System controls** shall be in accordance with Section 4.2.1G and H [M], 4.2.2D [P], and 4.2.2E [P]. The requirements are as follows:

    An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

    The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes in not more than an hour, whichever is less.

    The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

    The controls must include a **supply air temperature reset** function per Section 4.2.2G [P]. Both the hot deck and cold deck must incorporate the reset function. The controls should be capable of fully resetting the hot deck temperature from maximum design supply temperature down to return air temperature. Air flow rates to **interior zones** or other zones with relatively constant loads should be based on the fully reset temperature.

    A **mixed air temperature reset** should be included to minimize the impact of the economizer on the hot deck energy usage. This reset may be sequenced with the cold deck reset, or be reset on the basis of outdoor air temperatures or representative zone temperatures.

    When a unit serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down or set back independently of each other per Section 4.2.1H [M].

    Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down [M]. In addition, if ventilation air is provided through these dampers, the dampers must be controlled so that the minimum ventilation quantities are maintained during all times of occupancy [M]. The designer should refer to Section 4.2.1H for more information.

11. Ducts must be installed, sealed and insulated per Section 4.2.1J [M].

12. **Piping** for unit hot water coils or reheat coils must be insulated in accordance with Section 4.2.1I [M].

E. Dual-Fan Dual-Duct VAV

A dual-fan dual-duct VAV system is similar to a single-fan dual-duct VAV system except that the hot and cold decks each have their own fan .

This allows the hot deck to take air directly from the return while the cold deck is using economizer air. As a result, heating energy is minimized.

As with the single-fan dual-duct system, a pair of ducts delivers heated and cooled air to VAV mixing boxes in each zone. Each box modulates the flow of hot and cold air to its zone to maintain space temperature setpoint. The system will usually have an economizer on the cold deck; the hot deck may take air only from the return. Return/exhaust fans may also be incorporated.

The hot and cold decks may either be completely built-up, consist of air handlers with water coils, or be separate packaged units. For example, the hot deck may be a packaged rooftop gas furnace, and the cold deck may be a packaged rooftop DX unit.

Most of the requirements for the dual-fan dual-duct system are the same as for the single-fan dual-duct system. The following are the differences:

1. For dual fan systems, supply air flow includes the design cold deck supply, and the hot deck supply at the time of the cooling peak. Fan power is based on the design cold deck horsepower, and the hot deck fan power at the time of the cooling peak. Since the hot deck fan will normally be operating at a reduced air flow at the time of the cooling peak (or off), the hot deck fan horsepower may be determined on this basis. If unknown, the designer may assume that both hot deck airflow and power is 35 percent of design.

2. **Ventilation** may be delivered through the hot deck, the cold deck or both. If all ventilation air is provided through the cold deck, and the hot deck draws air only from the return, then the minimum cold duct cfm of the zone VAV box may be set to the required outdoor ventilation rate; the hot duct damper can close fully.

3. A fully integrated **economizer** with controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling [P]. This economizer may be on the cold deck only.

Example 4-29: Dual-Fan Dual-Duct Fan Power

Question

How is the fan power calculated for a dual-fan dual-duct VAV system having a 24,000 cfm, 25 BHP cold deck fan, and a 10,000 cfm, 9 BHP hot deck fan? Load calculations show that the hot deck will deliver 25 percent airflow at the time of the cooling peak. Both fans are modulated with variable frequency drives having efficiencies of 96 percent.

Answer

Assuming the belt drive efficiencies are 97 percent, and motor efficiencies are from Table B-8, the cold deck power is:

(25 BHP x 0.746kW/HP) / (0.88 x 0.97 x 0.96) = 22.8 kW

For the hot deck, assume that fan power will drop as the square of the airflow (the fan laws say the cube, but this is unrealistic). Power consumption at 25 percent airflow is then:

(9BHP x 0.746kW/HP) / (0.85 x 0.97 x 0.96) = 8.5 kW

8.5 kW x (2500cfm/10,000cfm)2 = 4.35 kW

Total power is:

22.8 kW + 4.3 kW = 27.0 kW

and total airflow is :

24,000 cfm + 2500 cfm = 26,500 cfm

so that system fan power is

(27.0 kW x 1000 W/kW) / 26,500 cfm = 1.0 W/cfm

4. **VAV Zone Controls** shall be in accordance with Section 4.2.1G and H [M] and Section 4.2.2 [P].

   The controls must be able to measure the airflow rate and control the supply so that the minimum airflow rate is maintained at all times [M]. For this reason, VAV controls should be of the **pressure independent** type; pressure dependent controls do not measure flow, and therefore should not be used. In a dual-duct VAV where all ventilation air is supplied through the cold duct, only the cold duct control need be pressure independent.

F. Packaged Terminal Air Conditioner with Gas-Furnace or Heat Pump

Packaged terminal air conditioners (PTAC) are units designed to supply heating and cooling to an individual space. They are usually smaller in capacity than packaged rooftop units, and are designed for through-the-wall installation. All PTAC units discharge air directly into the space without duct work. Cooling is provided by a compressor with direct expansion coil. Heating is provided by either using the compressor in a heat pump cycle or by a gas furnace. Units with electric resistance heating are also available, but their use is severely restricted by the *Standards*.

A PTAC unit is usually controlled directly by a thermostat that cycles the compressor on and off. This thermostat may be either integral to the unit or wall-mounted.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. Any **equipment** listed in Appendix B, Table B-9, shall comply with the listed efficiencies [M].

3. **Fan power consumption** is not regulated explicitly, as the requirements apply only to systems having fans 25 horsepower and larger.

4. **Ventilation** shall be in accordance with Section 4.2.1D - G [M]. For most office spaces, a minimum of 0.15 cfm/sf or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants may have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   Conference rooms, or other spaces having dense but intermittent occupancy levels, may require transfer fans or other mechanisms to accommodate their increased ventilation requirements.

5. An **economizer** is not required for PTAC units under 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F) [P]. Economizers are also not required for units serving residential living quarters and hotel/motel guest rooms.

6. With the exception of supplementary resistance heating as described below, **electric-resistance heating** (Section 4.2.2H) is permitted only where [P]:

   a. The total capacity of all electric resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building; or

   b. The total capacity of all electric resistance heating systems serving the building, excluding supplementary resistance heaters in heat pumps, is less than 3 kW.

   In practical terms, these exceptions allow a building with a single small PTAC to use resistance heat instead of a heat pump. A large building may have a few PTACs with electric heat, provided that 90 percent of the building's heating capacity is provided by other types of units. Any other building heated and cooled by PTACs must use heat pump PTACs.

   When a PTAC is specified with supplementary resistance heaters, the heat pump compressor capacity must be at least 75 percent of the design heating load at design conditions per Section 4.2.2H [P].

7. **Zone Controls** shall be in accordance with Section 4.2.1H [M] and 4.2.2D [P].

   A **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   If the PTAC unit is serving a **hotel/motel guest room**, the thermostat must have numeric temperature setpoints in °F and stop points accessible only to authorized personnel [M].

   Ventilation air must be provided at least 55 out of every 60 minutes (4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to On.

8. **System controls** shall be in accordance with Section 4.2.1H [M], and 4.2.2D [P]. The requirements are as follows:

   A **certified automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation. Systems serving hotel/motel guest rooms are exempt provided they have a readily accessible manual shut-off switch

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three air changes in not more than one hour, whichever is less. Systems serving hotel/motel guest rooms are exempt.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints (Section 4.2.1H)[M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F, or for hotel/motel guest rooms.

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down. Dampers are not required in hotel/motel guest rooms or other applications where exhaust fans run continuously.

   When a system serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other [M]. Since PTAC units serve areas smaller than this, isolation is accomplished by using separate automatic time switches for each unit or group of units.

9. **Heat pump thermostats and controls** must meet all of the requirements in items 7 and 8 above, and in addition must have controls[M]:

   a. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and

   b. In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.

   The controls may allow supplementary heating during:

   a. Defrost; and

   b. Transient periods such as start-up or raising the room thermostat setpoint if the controls provide preferential rate control, intelligent recovery, staging, ramping or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

G. *Four-Pipe Fan Coil System with Central Plant*

A four pipe fan coil (FPFC) is a small unit consisting of a fan, separate heating and cooling coils, a replaceable filter and a drain pan for condensate. FPFCs are available in various configurations to fit under windowsills, above furred ceilings and in vertical spaces within walls. Ventilation air can be provided through the wall or via a central ventilating system.

A central plant, consisting of a hot water boiler and chiller, provides heating and cooling to the fan coil units.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. Any **equipment** listed in Appendix B, Table B-9, shall comply with the listed efficiencies [M].

3. **Fan power consumption** is not regulated explicitly, as the requirements apply only to systems having fans 25 horsepower and larger.

4. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A) [P].

5. Ventilation shall be in accordance with Section 4.2.1.D - G [M]. For most office spaces, a minimum of 0.15 cfm/sf or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants may have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   Ventilation in through-the-wall units may be directly from the outdoors, although wind pressure may cause problems in this arrangement.

   When ventilation is via a central fan system, the duct work must deliver the required amount of air directly to each space. If the FPFC units are above the ceiling in a return plenum, then the ventilation air supply must be either directly connected to the unit or ducted to discharge either:

   a. Within 5 feet of the unit; or

   b. Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute (Section 4.2.1F).

6. An **economizer** is not required for FPFC units under 2,500 cfm supply air and 75,000 Btu/hr cooling [P]. Economizers are also not required for units serving residential living quarters and hotel/motel guest rooms.

   Water-side economizers should be evaluated for buildings in favorable climates.

7. **Electric resistance heating** for local heating, etc. is prohibited in most circumstances [P]. The designer should refer to Section 4.2.2H for the exceptions.

8. **Zone Controls** shall be in accordance with Section 4.2.1H [M] and 4.2.2D [P].

   A **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   Ventilation air must be provided at least 55 out of every 60 minutes (4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to **On**. This is not required if a central system is used to deliver ventilation air independent of unit fan operation.

9. **System controls** shall be in accordance with Section 4.2.1G and H[M], and 4.2.2D and E. [P]. The requirements are as follows:

   An **automatic time switch** with weekday/ weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three air changes per hour, whichever is less. If a central ventilation system is used to supply ventilation air directly to the space, then unit fans do not need to be started ahead of time.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down. Dampers are not required in hotel/motel guest rooms or other applications where exhaust fans will operate continuously.

   When a system serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other [M]. Since FPFC units serve areas smaller than this, isolation is accomplished by using separate automatic time switches for each unit or group of units.

10. **Ducts, if any,** must be installed, sealed and insulated per Section 4.2.1J [M]. Ducts must be insulated in compliance with UMC Section 1005 or Section 4.2.1J [M].

11. **Piping** for unit hot and chilled water coils must be insulated in accordance with Section 4.2.1.I [M].

H. Water Loop Heat Pump System with Central Plant

Water loop heat pumps (WLHP) provide heating and cooling for a number of individually controlled zones by operation of water-to-air heat pump units located in each space. Each heat pump is piped to a common circulation loop and will take heat from, or reject heat to the loop, depending on whether the unit is in the heating or cooling mode.

During some periods, the thermal requirements of units in the heating mode will balance with the units in the cooling mode, and the loop will remain at a constant temperature. At other times the loop will be out of balance, and heat must be made up by a boiler or rejected by a cooling tower.

WLHPs are available in various sizes and configurations to fit under windowsills, above furred ceilings, stacked in vertical spaces within walls, in mechanical rooms, and on rooftops. Small units are often used for each exterior space, with larger units serving the interior.

Ventilation air can be provided through the wall in perimeter units, or via a central ventilating system.

A central plant, consisting of a hot water boiler and cooling tower, provides supplemental heating and heat rejection for the loop.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. Any **equipment** listed in Appendix B, Table B-9, of Appendix B shall comply with the listed efficiencies [M]**.**

3. **Fan power consumption** must be no more than 0.8 Watts/cfm of supply air for constant volume systems, in accordance with Section 4.2.2C [P]. The limit applies to the sum of the horsepower of all supply, return, and exhaust fans in the space-conditioning system that operates during the peak design period. Space exhaust fans such as toilet exhausts are included, while economizer fans that do not operate at peak are excluded.

   The limit does not apply to any system having fans totaling less than 25 HP. Because most WLHP systems are relatively small, fan horsepower will not usually be a consideration.

4. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A).

5. **Ventilation** shall be in accordance with Section 4.2.1C [M]. For most office spaces, a minimum of 0.15 cfm/sf or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants may have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   Ventilation in through-the-wall units may be directly from the outdoors, although wind pressure may cause problems in this arrangement.

   When ventilation is via a central fan system, the duct work must deliver the required amount of air directly to each space. If the WLHP units are above the ceiling in a return plenum, then the ventilation air supply must be either directly connected to the unit or ducted to discharge either:

   a. Within five feet of the unit; or

   b. Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute (Section 4.2.1F).

6. A fully integrated **economizer** with controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F)[P]. A water economizer must meet 100 percent of the expected system cooling load as calculated at outside air temperatures of 50°F dry-bulb and 45°F wet-bulb and below.

7. **Electric resistance heating** for local heating, etc. is prohibited in most circumstances [P]. The designer should refer to Section 4.2.2H for the exceptions.

   Electric boilers for supplemental loop heating are not allowed unless it can be demonstrated to the satisfaction of the enforcement agency that at least 60 percent of the annual heating energy requirement is supplied by site solar or recovered energy.

8. **Zone Controls** shall be in accordance with Section 4.2.1H [M] and 4.2.2D [P].

   A **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   Ventilation air must be provided at least 55 out of every 60 minutes (Section 4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to **On**. This is not required if a central system is used to deliver ventilation air independently of unit fan operation.

9. **System controls** shall be in accordance with Section 4.2.1G and H [M], and 4.2.2D [P]. The requirements are as follows:

An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes, whichever is less. If a central ventilation system is used to supply ventilation air directly to the space, then unit fans do not need to be started ahead of time.

The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints (Section 4.2.1H) [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down.

When a system serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other [M]. Since WLHP units normally serve areas smaller than this, isolation is accomplished by using separate automatic time switches for each unit or group of units.

10. **Ducts, if any** must be installed, sealed and insulated per Section 4.2.1J [M].

11. **Piping** must be insulated in accordance with Section 4.2.1I [M]. Note that piping for WLHPs will not normally need to be insulated.

4.3 MECHANICAL PLAN CHECK DOCUMENTS

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the forms and recommended procedures documenting compliance with the mechanical requirements of the *Standards*. It does not describe the details of the requirements; these are presented in Section 4.2 Mechanical Design Procedures. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the building department plan checkers who are examining those documents for compliance with the *Standards*.

The use of each form is briefly described below, then complete instructions for each form are presented in the following subsections. The information and format of these forms may be included in the equipment schedule.

MECH-1: Certificate of Compliance
This form is required for every job, and it is required to appear *on the plans*.

MECH-2: Mechanical Equipment Summary
This form summarizes the major components of the heating and cooling systems, and documents compliance with the minimum efficiency, economizer and VAV airflow requirements.

MECH-3: Mechanical Ventilation
This form documents the calculations used as the basis for the outdoor air ventilation rates. For VAV systems, it is also used to show compliance with the reduced airflow rates necessary before reheating, recooling or mixing of conditioned airstreams.

MECH-4: Mechanical Sizing and Fan Power
This form is used to list the size of all equipment regulated by these *Standards*, and to document compliance with the fan power limitations.

4.3.1 MECH-1: Certificate of Compliance

MECH-1 is the primary mechanical form. Its purpose is to provide compliance information in a form useful to the enforcement agency's field inspectors.

This form should be included on the plans, usually near the front of the mechanical drawings. A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the Energy Commission's forms), provided the information is the same and in similar format. Additionally, if none of the information requested for Part 2 of 2 of this form applies to the job, the building department does not have to require that these parts be included on the plans.

A. Project Description

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

3. **PROJECT ADDRESS** is the address of the project as shown on the plans and known to the building department.

4. **PRINCIPAL DESIGNER - MECHANICAL** is the person responsible for the preparation of the mechanical plans, and the person who signs the STATEMENT OF COMPLIANCE (see below). The person's telephone number is given to facilitate response to any questions that arise.

5. **DOCUMENTATION AUTHOR** is the person who prepared the energy compliance documentation. This may or may not be the principal designer (it may be a person specializing in *Standards* compliance work). The person's telephone number is given to facilitate response to any questions that arise..

6. **ENFORCEMENT AGENCY USE** is reserved for building department record keeping purposes.

B. General Information

1. **DATE OF PLANS** is the last revision date of the plans. If the plans are revised after this date, it may be necessary to re-submit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.

2. **BUILDING CONDITIONED FLOOR AREA** has specific meaning under the *Standards*. See Section 2.1.2A for a discussion of this definition.

   The number entered here should match the floor area entered on form ENV-1.

3. **BUILDING TYPE** is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the *Nonresidential Standards* are designated "Nonresidential" here. It is possible for a building to include more than one building type. See Section 2.1.2B for the formal definitions of these occupancies.

4. **PHASE OF CONSTRUCTION** indicates the status of the building project described in the documents. Refer to Section 2.2 for detailed discussion of the various choices.

   a. **NEW CONSTRUCTION** should be checked for all new buildings (see Section 2.2.6), newly conditioned space (see Section 2.2.2) or for new construction in existing buildings (tenant improvements, see Section 2.2.3) which are submitted for envelope compliance.

   b. **ADDITION** should be checked for an addition which is not treated as a stand-alone building, but which uses Option 2 described in Section 2.2.5.

c. **ALTERATION** should be checked for alterations to existing building mechanical systems (see Section 2.2.4).

5. **METHOD OF MECHANICAL COMPLIANCE** indicates which method is being used and documented with this submittal:

   a. **PRESCRIPTIVE** should be checked if the mechanical systems comply using only the mandatory and prescriptive measures.

   b. **PERFORMANCE** should be checked when the performance method is used to show compliance. All required performance documentation must be included in the plan check submittal when this method is used.

6. **PROOF OF ENVELOPE COMPLIANCE** indicates how the envelope has been shown to comply. The envelope must comply before a permit to install a mechanical system is granted:

   a. **PREVIOUS ENVELOPE PERMIT** indicates that the envelope has already been shown to comply. If so, the building department will have the envelope forms on file. This method is typically used for alterations to existing space.

   b. **ENVELOPE COMPLIANCE ATTACHED** - is typically used for new buildings.

C. Statement of Compliance

The Statement of Compliance is signed by both the Documentation Author (described above in section 4.3.1.A.) and the person responsible for preparation of the plans for the building. This latter person is also responsible for the energy compliance documentation, even if the actual work is delegated to a different person acting as Documentation Author. It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the *Business and Professions Code*, referenced on the Certificate of Compliance, are provided below:

Applicable sections from the *Business and Professions Code* (based on the edition in effect as of April 1998), referenced on the Certificate of Compliance are provided below:

5537. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible

for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. *This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.*

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. *This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:*

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

6737.3. *A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services* *he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.*

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person

D. Mechanical Mandatory Measures

The Mandatory Measures must be incorporated into the construction documents. The designer may use whatever format is most appropriate for specifying the mandatory measures in the plan set. In general, this will take the form of a notes block near the front of the set, possibly with cross-references to other locations in the plans where measures are specified. This space should be used to indicate the sheet number(s) on the plans where these notes can be found.

A sample, generic mechanical mandatory measures note block is shown in Example 4-30. This particular format allows the designer to check the appropriate boxes to indicate the applicable mandatory measures.

Example 4-30: Sample Notes - Mechanical Mandatory Measures

Equipment and Systems Efficiency

- Any appliance for which there is a California standard established in the Appliance Efficiency Standards may be installed only if the manufacturer has certified to the Energy Commission, as specified in those regulations, that the appliance complies with the applicable standard for that appliance. Included are room air conditioners, central air conditioning heat pumps (regardless of capacity, except that requirements for central air conditioning heat pumps with cooling capacity of 135,000 Btu/hr or more apply to heating performance but not cooling performance), other central air conditioners with a cooling capacity less than 135,000 Btu/hr, fan type central furnaces with input rate less than 400,000 Btu/hr, boilers wall furnaces, floor furnaces, room heaters, unit heaters and duct furnaces shall have been certified to the Energy Commission by its manufacturer to comply with the Appliance Efficiency Standards.

- The following space-conditioning equipment may be installed only if the manufacturer has certified that the equipment meets or exceeds all applicable efficiency requirements listed in Section 112 of the *Standards*: all air conditioners, heat pumps and condensing units >135,000 Btu/hr; all water chillers; all gas-fired boilers >300,000 Btu/hr; all oil-fired boilers >225,000 Btu/hr; and all warm air furnaces and combination warm air furnaces/air-conditioning units >225,000 Btu/hr. Fan type central furnaces shall not have a pilot light.

- Piping, except those conveying fluids at temperatures between 60°F and 105°F, or within HVAC equipment, shall be insulated in accordance with *Standards* Section 123.

- Air handling duct systems shall be constructed, installed, sealed and insulated as provided in Chapter 10 of the Uniform Mechanical Code.

Controls

- Each space-conditioning system serving building types such as offices and manufacturing facilities (and all others not explicitly exempt from the requirements of Section 112(d)) shall be installed with an automatic time switch with an accessible manual override that allows operation of the system during off-hours for up to four hours. The time switch shall be capable of programming different schedules for weekdays and weekends; and has program backup capabilities that prevent the loss of the device's program and time setting for at least 10 hours if power is interrupted.

- Each space-conditioning system shall be installed with an occupancy sensor to control the operating period of the system.

- Each space-conditioning system shall be installed with a four-hour timer that can be manually operated to control the operating period of the system.

- Each space-conditioning system shall be installed with controls that temporarily restart and temporarily operate the system as required to maintain a setback heating thermostat setpoint.

- Each space-conditioning system shall be installed with controls that temporarily restart and temporarily operate the system as required to maintain a setback cooling thermostat setpoint.

- Each space-conditioning system serving multiple zones with a combined conditioned floor area more than 25,000 square feet shall be provided with isolation zones. Each zone shall:

Example 4-30: Sample Notes (cont'd)

  - not exceed 25,000 square feet; shall be provided with isolation devices, such as valves or dampers, that allow the supply of heating or cooling to be

  - setback or shut off independently of other isolation areas; and shall be controlled by a time control device as described above.

- Each space-conditioning zone shall be controlled by an individual thermostatic control that responds to temperature within the zone. Where used to control heating, the control shall be adjustable down to 55°F or lower. For cooling, the control shall be adjustable up to 85°F or higher. Where used to control both heating and cooling, the control shall be capable of providing a dead band of at least 5°F within which the supply of heating and cooling is shut off or reduced to a minimum.

- Thermostats shall have numeric setpoints in °F.

- Thermostats shall have adjustable setpoint stops accessible only to authorized personnel.

- Heat Pumps shall be installed with controls to prevent electric resistance supplementary heater operation when the heating load can be met by the heat pump alone. Electric resistance supplementary heater operation is permitted during transient periods, such as start-ups and following room thermostat setpoint advance, when controls are provided which use preferential rate control, intelligent recovery, staging, ramping, or similar control mechanisms designed to preclude the unnecessary operation of supplementary heating during the recovery period. Supplementary heater operation is also permitted during defrost.

Ventilation

- Controls shall be provided to allow outside air dampers or devices to be operated at the ventilation rates as specified in these plans.

- Gravity or automatic dampers interlocked and closed on fan shutdown shall be provided on the outside air intakes and discharges of all space-conditioning and exhaust systems.

- All gravity ventilating systems shall be provided with automatic or readily accessible manually operated dampers in all openings to the outside, except for combustion air openings.

Completion and Balancing

- All ventilation systems shall be documented per California Safety Code (Title 8, Section 5142(b)) to be providing the minimum required ventilation rate as determined using one of the following procedures:

  (1) Air Balancing: all space-conditioning and ventilation systems shall be balanced to the quantities specified in these plans, in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983), or Associated Air Balance Council (AABC) National Standards (1989).

  (2) Outside Air Certification: The system shall provide the minimum outside air as shown on the mechanical drawings, and shall be measured and certified by the installing licensed C-20 mechanical contractor.

  (3) Outside Air Measurement: The system shall be equipped with a calibrated local or remote device capable of measuring the quantity of outside air on a continuous basis and displaying that quantity on a readily accessible display device.

  (4) Another method approved by the Energy Commission.

Service Water Heating Systems

- The following service water heating systems and equipment may be installed only if the manufacturer has certified that the equipment meets or exceeds all applicable efficiency requirements listed in the *Appliance Efficiency Regulations* or Appendix B, Table B-9.

Example 4-30: Sample Notes (cont'd)

- Unfired service water heater storage tanks and backup tanks for solar water heating systems shall have either:
  - external insulation with an installed R-value of at least R-12; internal and external insulation with a combined R-value of at least R-16; or
  - sufficient insulation so that the heat loss of the tank surface based on an 80°F water-air temperature difference shall be less than 6.5 Btu/hr/sf.
- If a circulating hot water system is installed, it shall have a control capable of automatically turning off the circulating pump(s) when hot water is not required.
- Lavatories in restrooms of public facilities shall be equipped with either:
  - Outlet devices that limit the flow of hot water to a maximum of 0.5 gallons per minute
  - Foot actuated control valves, and outlet devices that limit the flow of hot water to a maximum of 0.75 gallons per minute.
  - Proximity sensor actuated control valves, and outlet devices that limit the flow of hot water to a maximum of 0.75 gallons per minute.
  - Self-closing valves, and outlet devices that limit the flow of hot water to a maximum of 2.5 gallons per minute, and 0.25 gallons/cycle (circulating system).
  - Self-closing valves, and outlet devices that limit the flow of hot water to a maximum of 2.5 gallons per minute, and 0.50 gallons/cycle (non-circulating system).
  - Self-closing valves, and outlet devices that limit the flow of hot water to a maximum of 2.5 gallons per minute, and 0.75 gallons/cycle (foot switches and proximity sensor controls).

- Lavatories in restroom of public facilities shall be equipped with controls to limit the outlet temperature to 110°F.

Pools and Spas

- Pool and/or spa heating systems or equipment shall be installed only if the manufacturer has certified that the system or equipment meets the requirements of Sections 114 and 115 of the *Standards*. Equipment shall not have a pilot light. All such systems shall be installed with at least 36 inches of pipe between the filter and the heater to allow for the future addition of solar heating equipment.
- A cover shall be provided for outdoor pools.
- A cover shall be provided for outdoor spas.
- Pools shall be installed with directional inlets that adequately mix the pool water.
- Pool circulation pump(s) shall be provided with a time switch that allows the pump to be set to run in the off-peak electrical demand period, and for the minimum time necessary to maintain the water in the conditions required by applicable public health standards.

To verify certification, use one of the following options:

1. The Energy Hotline (see above) can verify certification of appliances not found in the above directories.
2. The Energy Commission's Web Site includes listings of energy efficient appliances for several appliance types. The web site address is www.energy.ca.gov/efficiency/appliances.
3. The complete appliance databases can be downloaded from the Energy Commission's internet FTP site (FTP://sna.com/pub/users/efftech/appliance/). This requires database software (spreadsheet programs cannot handle some of the larger files). To use the data, a user must download the database file (or files), download a brand file and a manufacturer file and then decompress

these files. Then download a description file that provides details on what is contained in each of the data fields. With these files, and using database software, the data can be sorted and manipulated.

4. The Air Conditioning and Refrigeration Institute (ARI) Directory of Certified Unitary Products and Directory of Certified Applied Air-Conditioning Products can be used to verify certification of air-conditioning equipment.

E. System Features

This section is used to identify the mandatory and prescriptive features that will be verified by the field inspector. The form has columns for up to 3 systems. Additional forms should be attached for additional systems. When systems are identical, a single column may be used, and all systems listed in the **SYSTEM NAME** field. A **CODE TABLE** found toward the bottom of the form lists the acceptable entries. Either the abbreviation or the full entry is acceptable. Fields that are not applicable may be left blank or designated “N/A”.

1. **SYSTEM NAME** is the name of the system as shown on the plans.

2. **TIME CONTROL** indicates the type of time control device for this system:

   S Programmable time switch with weekday/weekend features.

   O Occupancy sensor, for intermittently occupied spaces only

   M Manual timer, for intermittently occupied spaces only

3. **SETBACK CONTROL** indicates whether controls which can restart the equipment based on space temperature during off-hours are required:

   H Heating: Required if design heating temperature is less than 32°F

   C Cooling: Required if design cooling temperature is greater than 100°F

   B Both

4. **ISOLATION ZONES** indicates the number of isolation zones that are required when the area served by a single HVAC system exceeds 25,000 square feet.

5. **HEAT PUMP THERMOSTAT** indicates that the system incorporates a heat pump which will be directly controlled by a heat pump thermostat which minimizes the use of electric resistance heat.

6. **ELECTRIC HEAT** indicates whether any electric heat is approved for this system. The capacity in kW and the location (system, room number, etc.) should be indicated in the field notes.

7. **FAN CONTROL** indicates the type of modulation the supply and return fans will have in a variable air volume system. For fan systems over 25 hp, the modulation must achieve at least a 50 percent power reduction at 70 percent airflow. The choices are:

   C for a fan that rides the curve. This is suitable only for forward-curved fans.

   I for inlet vanes. Normally, this is suitable only for forward-curved fans. If used with airfoil/backward inclined fans, manufacturer’s data showing a 70 percent power reduction at 50 percent airflow must be attached to the form.

   P for variable pitch vanes.

   V for variable frequency drive or variable-speed drive.

   O for other. Manufacturer’s data showing a 70 percent power reduction at 50 percent airflow must be attached to the form.

8. **VAV MIN POSITION CONTROL** is used for variable air volume systems only, and indicates that the plans must include a schedule of VAV boxes showing the minimum required airflow to each space.

9. **SIMULTANEOUS HEAT/COOL** indicates that a constant-volume type system will be using simultaneous heating and cooling in order to serve a space with special requirements (humidity control, constant ventilation, etc.)

   If the system serves more than one space, the field notes should indicate the spaces in which this is allowed.

10. **HEAT AND COOL SUPPLY RESET** is required for systems which reheat, recool, or mix conditioned air streams, and indicates that a supply air temperature reset must be incorporated into the control sequences.

11. **VENTILATION** indicates the manner in which compliance with the ventilation requirements will be achieved:

    B **Air Balance**: Indicates that an air balance will be made by a certified air balance contractor. The inspector should ask to see a copy of the balance report.

    C **Outside Air Certification**: Indicates that the installing licensed C-20 mechanical contractor will measure the outdoor airflow and adjust the system and controls so that the minimum required outdoor ventilation rate is delivered under all operating conditions. A statement indicating that the system provides the minimum outside air as shown on the mechanical drawings must be signed by either the design mechanical engineer, the installing licensed C-20 contractor, or the person with overall responsibility for the design of the ventilation system. The certificate must be presented to the inspector before an occupancy permit is granted.

    M **Measurement**: The system will be equipped with a calibrated device capable of measuring the quantity of outside air and displaying the value.

    D **Demand Control**: The system will be equipped with a demand control ventilation device which will be installed and adjusted to control carbon dioxide (CO_2) levels.

    N **Natural Ventilation**: Operable openings will provide natural ventilation.

12. **OUTDOOR DAMPER CONTROL** indicates the type of controls used to close system intake and exhaust dampers during off hours:

    A **Automatic** motorized damper controls

    G **Gravity** type backdraft dampers

13. **ECONOMIZER TYPE** is used to indicate whether a space-conditioning system has an economizer, and the type. The choices are **AIR**, **WATER** or **N/A**.

14. **DESIGN O.A. AIR CFM** indicates the minimum airflow that the space-conditioning system must continuously provide during all occupied hours (from MECH-3, Column H).

15. **HEATING EQUIPMENT TYPE** identifies the type of heating equipment that the field inspector will check for this system. Generic entries such as Boiler or Gas Furnace are acceptable. See Appendix B, Table B-9

    a. **HIGH EFFICIENCY** indicates that the equipment installed has an efficiency higher than required by the *Standards*, and that this higher efficiency was used in the Performance Method to demonstrate compliance with the *Standards*.

       This box should also be checked when higher efficiency equipment is installed as part of a utility rebate program.

    b. **IF YES ENTER EFF. #** if the **HIGH EFFICIENCY** box is checked enter the equipment efficiency and unit here (i.e. AFUE, Thermal EFF, COP).

    c. **MAKE AND MODEL NUMBER** is for the heating equipment identified on the

previous line. This entry should match the entry listed on the MECH-2 form.
It is recognized that the actual make and model of equipment installed is often different from that specified. If so, and if **HIGH EFFICIENCY** is indicated, the substitute equipment must be at least as efficient as the equipment originally specified. Enter the equipment efficiency and unit here (i.e. AFUE, Thermal EFF, COP).

Manufacturer's performance data for substitute equipment must be resubmitted to the building department for approval. Upon reapproval, the building department should make notes to that effect in the **NOTE TO FIELD** column.

16. **COOLING EQUIPMENT TYPE** is identical to HEATING EQUIPMENT TYPE described above. Note that, when substitute HIGH EFFICIENCY. equipment is used, the equipment must satisfy all specified efficiency indicators, including SEER, EER, IPLV, etc. See Appendix B, Table B-9

17. **PIPE INSULATION REQUIRED** should list the function of the pipe when pipe insulation is required. Appropriate entries might be supply, return, nonrecirculating or recirculating (for service water), chilled supply, etc.

18. **PIPE TYPE** is supply, return, etc.

19. **HEATING DUCT LOCATION** indicates the location of the duct work for the purposes of establishing the ambient temperature. Most common locations include:

    a. **Conditioned** - for duct work located directly within the conditioned space.

    b. **Plenum** - for duct work located above a ceiling, but below an insulated roof

    c. **Attic** - for duct work located above an insulated ceiling, and below an uninsulated roof.

    d. **Unconditioned** - for duct work running through spaces that are not conditioned.

    e. **Roof** - for duct work exposed on a roof.

20. **DUCT R-VALUE** is the required R-value of the duct insulation, based on duct location and climate. If the designer has specified a higher R-value, the higher value should be entered instead.

21. **COOLING DUCT LOCATION/DUCT R-VALUE** is identical to HEATING DUCT LOCATION and DUCT R-VALUE.

22. **DUCT TAPE ALLOWED?** Indicate a Yes or No as to whether pressure-sensitive duct tape is used.

F. Notes To Field

This column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance.

G. Sample Form: MECH-1 Certificate of Compliance

CERTIFICATE OF COMPLIANCE (Part 1 of 2) MECH-1

PROJECT NAME		DATE
PROJECT ADDRESS		
PRINCIPAL DESIGNER-MECHANICAL	TELEPHONE	Building Permit #
DOCUMENTATION AUTHOR	TELEPHONE	Checked by/Date Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA

BUILDING TYPE ☐ NONRESIDENTIAL ☐ HIGH RISE RESIDENTIAL ☐ HOTEL/MOTEL GUEST ROOM

PHASE OF CONSTRUCTION ☐ NEW CONSTRUCTION ☐ ADDITION ☐ ALTERATION ☐ UNCONDITIONED (file affidavit)

METHOD OF MECHANICAL COMPLIANCE ☐ PRESCRIPTIVE ☐ PERFORMANCE

PROOF OF ENVELOPE COMPLIANCE ☐ PREVIOUS ENVELOPE PERMIT ☐ ENVELOPE COMPLIANCE ATTACHED

STATEMENT OF COMPLIANCE

This Certificate of Compliance lists the building features and performance specifications need to comply with Title 24, Parts 1 and 6 of the California Code of Regulations. This certificate applies only to building mechanical requirements.

The documentation preparer hereby certifies that the documentation is accurate and complete.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Mechanical Designer hereby certifies that the proposed building design represented in this set of construction documents is consistent with the other compliance forms and worksheets, with the specifications, and with any other calculations submitted with this permit application. The proposed building has been designed to meet the mechanical requirements contained in the applicable parts of Sections 110 through 115, 120 through 124, 140 through 142, 144 and 145.

Please check one:

☐ I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for it's preparation; and that I am licensed in the State of California as a civil engineer or mechanical engineer, or I am a licensed architect.

☐ I affirm that I am eligible under the exemption to Division 3 of the Business and Professions Code by Section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ I affirm that I am eligible under the exemption to Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described pursuant to Business and Professions Code sections 5537, 5538, and 6737.1.

(These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

PRINCIPAL MECHANICAL DESIGNER-NAME	SIGNATURE	DATE	LIC. #

MECHANICAL MANDATORY MEASURES

Indicate location on plans of Note Block for Mandatory Measures ____________________

INSTRUCTIONS TO APPLICANT

For Detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the Nonresidential Manual published by the California Energy Commission.
MECH-1: Required on plans for all submittals. Part 2 may be incorporated in schedules on plans.
MECH-2: Required for all submittals, but may be incorporated in schedules on plans.
MECH-3: Required for all submittals unless required ventilation rates and airflows are shown on plans, See 4.3.4.
MECH-4: Required for all prescriptive submittals.

CERTIFICATE OF COMPLIANCE (Part 2 of 2) MECH-1

PROJECT NAME	DATE

SYSTEM FEATURES

SYSTEM NAME		MECHANICAL SYSTEMS						NOTE TO FIELD Bldg. Dept. Use
TIME CONTROL								
SETBACK CONTROL								
ISOLATION ZONES								
HEAT PUMP THERMOSTAT?								
ELECTRIC HEAT?								
FAN CONTROL								
VAV MINIMUM POSITION CONTROL?								
SIMULTANEOUS HEAT/COOL?								
HEAT AND COOL SUPPLY RESET?								
VENTILATION								
OUTDOOR DAMPER CONTROL?								
ECONOMIZER TYPE								
DESIGN O.A. CFM (MECH-3, COLUMN H)								
HEATING EQUIPMENT TYPE								
HIGH EFFICIENCY?	IF YES ENTER EFF. #							
MAKE AND MODEL NUMBER								
COOLING EQUIPMENT TYPE								
HIGH EFFICIENCY?	IF YES ENTER EFF. #							
MAKE AND MODEL NUMBER								
PIPE INSULATION REQUIRED?								
PIPE TYPE (SUPPLY, RETURN, ETC.)								
HEATING DUCT LOCATION	R-VALUE							
COOLING DUCT LOCATION	R-VALUE							
DUCT TAPE ALLOWED?								

CODE TABLES: Enter code from table below into columns above.

HEAT PUMP THERMOSTAT?	Y: Yes N: No
ELECTRIC HEAT?	
VAV MINIMUM POSITION CONTROL?	
SIMULTANEOUS HEAT/COOL?	
HEAT AND COOL SUPPLY RESET?	
HIGH EFFICIENCY?	
DUCT TAPE ALLOWED?	
PIPE INSULATION REQUIRED?	

TIME CONTROL	SETBACK CTRL.	ISOLATION ZONES	FAN CONTROL
S: Prog. Switch O: Occupancy Sensor M: Manual Timer	H: Heating C: Cooling B: Both	Enter number of Isolation Zones	I: Inlet Vanes P: Variable Pitch V: VFD O: Other C: Curve

VENTILATION	OUTDOOR DAMPER	ECONOMIZER	DESIGN O.A. CFM
B: Air Balance C: Outside Air Cert. M: Outside Air Measure D: Demand Control N: Natural	A: Auto G: Gravity	A: Air W: Water N: Not Required	Enter Design Outdoor Air CFM. Note: This shall be no less than Column H on MECH-3.

4.3.2 MECH-2: Mechanical Equipment Summary

This form is used to summarize all space-conditioning equipment whose efficiency is regulated by either these *Standards* or the *Appliance Efficiency Standards*. Only equipment subject to these regulations should be listed; air handlers, pumps, cooling towers and other unregulated equipment should not be listed. As many copies of this form should be used as are needed to list all equipment.

Note that, while air handlers are not listed on this form, their airflow and fan power consumption must be included on MECH-4.

The designer may elect to include the information on this form as part of Equipment Schedules on the drawings. If so, then this form may be left blank, except for a note identifying the drawing page(s) where this information may be found.

A. Chiller and Tower Summary

1. **EQUIPMENT NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **EQUIPMENT TYPE** lists the type of chiller. Chiller types include centrifugal or reciprocating.

   a. Centrifugal: Compression refrigeration system using rotary centrifugal compressor.

   b. Reciprocating. Compression refrigeration system using reciprocating positive displacement compressor.

3. **QTY.** is the number of each unique equipment type.

4. **EFFICIENCY** is the efficiency at the test conditions as specified in Appendix B, Table B-9, Minimum Mechanical Equipment Efficiencies.

5. **TONS** is the equipment capacity (12,000 Btu is equivalent to 1 ton).

6. **PUMPS**

   a. **TOT. QTY** is the number of pumps.

   b. **GPM** is the flow rate in gallons per minute.

   c. **BHP** is the pump brakehorsepower.

   d. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

   e. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

   f. **PUMP CONTROL** is the control type, which is either variable flow, riding curve or two speed/stages).

B. DHW/Boiler Summary

1. **SYSTEM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **SYSTEM TYPE** includes:

   a. Boilers: electric, fossil fuel, natural draft, forced/induced draft or hot water.

   b. Water Heaters: electric or gas.

3. **DISTRIBUTION TYPE** is standard or recirculating.

4. **QTY.** is the number of individual boilers or tanks in the system.

5. **RATED INPUT** is the rated input capacity listed in certification information for the water heater (in Btu/hr).

6. **VOL. (GALS.)** is volume in gallons of the water heater or storage tank.

7. **ENERGY FACTOR OR RECOVERY EFFICIENCY** is the efficiency of the water heater tank. If water heating is provided by a boiler, the efficiency (thermal efficiency) must include the effects of the storage tank. All efficiencies shall be in accordance with Table B-9 in Appendix B

8. **STANDBY LOSS OR PILOT ENERGY** is standby loss for large (greater than 75,000 Btu/hr) or pilot energy (in Btu/hr) for instantaneous water heaters and large storage (boiler) gas heater type. Enter 0 for no pilot, or 800 if pilot exists.

9. **TANK INSUL.** is the external R-value of insulation on an unfired storage tank.

C. Central System Ratings

1. **SYSTEM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **SYSTEM TYPE** is furnace, heat pump, hydronic or Direct expansion (DX) compressors.

3. **QUANTITY** is the number of unique system types.

4. **HEATING**

   a. **OUTPUT** is the heating capacity in Btu/hr at the design conditions. When using the Prescriptive Approach, this number must not exceed the maximum adjusted load (last line of **2. Sizing**) as calculated on MECH-4, unless an exception was taken on that form. It should also be consistent with the total capacity as indicated on MECH-4.

   b. **AUX. kW** is any auxiliary or supplemental electric heating (in kW) which is typically installed in a Heat Pump system.

   c. **EFFICIENCY** is the efficiency at the test conditions as specified in Appendix B, Table B-9, Minimum Mechanical Equipment Efficiencies.

5. **COOLING**

   a. **OUTPUT** is the cooling capacity in Btu/hr at the design conditions. When using the Prescriptive Approach, this number must not exceed the maximum adjusted load (last line of **2. Sizing**) as calculated on MECH-4, unless an exception was taken on that form. It should also be consistent with either the sensible or total capacity as indicated on MECH-4.

   b. **SENSIBLE** is sensible cooling capacity at the design conditions, based on equipment manufacturer's ratings.

   c. **EFFICIENCY** is the efficiency at the test conditions as specified in Appendix B, Table B-9, Minimum Mechanical Equipment Efficiencies.

   d. **ECONOMIZER TYPE** is used for space-conditioning equipment to indicate an air or water economizer. An economizer is not required for chillers.

D. Central Fan Summary

1. **SYSTEM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **FAN TYPE** may be constant volume, inlet vane, discharge damper or variable speed, and is used to document compliance with the fan power requirements of Section 144(c) of the *Standards.*

3. **SUPPLY FAN**

   a. **MOTOR LOCATION** is in airstream or outside airstream.

b. **CFM** is the airflow at the design conditions. When using the Prescriptive Approach, this number must match the cfm listed for the supply fan on form MECH-4,**FAN POWER CONSUMPTION**, Column G.

c. **BHP** is supply fan brakehorsepower (see Section 4.2.2.C). When using the Prescriptive Approach, this number must be listed on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

d. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

e. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

4. **RETURN FAN** information includes fan CFM, brakehorsepower, and motor and drive efficiency (see SUPPLY FAN above and Section 4.2.2.C).

a. **CFM** is the airflow at the design conditions.

b. **BHP** is return fan brake horsepower (see Section 4.2.2.C). When using the Prescriptive Approach, this number must be listed on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

c. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

d. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

E. VAV Summary

1. **ZONE NAME** lists the equipment tag or other identifier as shown on the drawings.

If more than one space-conditioning system is identical, all may be listed on a single line.

2. **VAV**

a. **SYSTEM TYPE** is CAV, VAV, VAV with series fan or VAV with parallel fan, and is used to specify the type of VAV box, and what type of fan is included.

b. **QUANTITY** is the total number of identical VAV boxes.

c. **MINIMUM CFM RATIO** is the minimum design air flow rate, which is used to document compliance with Section 144(d) of the *Standards*.

d. **REHEAT COIL**

- **TYPE** is hot water or electric. Note that when using the Prescriptive Approach, electric reheat is only allowed as listed under Section 144(g) of the *Standards.*

- **DELTA T** is the temperature difference at which heat is supplied.

3. FAN

a. **FLOW RATIO** is used to specify the ratio of airflow in a Parallel Fan or Series Fan powered VAV box.

b. **CFM** is the total airflow at the design conditions for a fan powered VAV box.

c. **BHP** is supply fan brakehorsepower (see Section 4.2.2.C). When using the Prescriptive Approach, this number must be included on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

d. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

e. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device’s efficiency.

f. **BASEBOARD TYPE AND OUTPUT**

F. Exhaust Fan Summary

1. **ROOM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **QTY** is the total number of identical exhaust fans.

3. **CFM** is the total airflow at the design conditions for an exhaust fan.

4. **BHP** is the exhaust fan brake horsepower (see Section 4.2.2.C). When using the Prescriptive Approach, this number must be included on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

5. **MOTOR EFF.** is from equipment information or from Appendix B, Table B-8.

6. **DRIVE EFF.** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device’s efficiency.

F. Sample Form: MECH-2 Mechanical Equipment Summary

MECHANICAL EQUIPMENT SUMMARY (Part 1 of 2) MECH-2

PROJECT NAME	DATE

CHILLER AND TOWER SUMMARY

					PUMPS					
Equipment Name	Equipment Type	Qty.	Efficiency	Tons	Total Qty.	GPM	BHP	Motor Eff.	Drive Eff.	Pump Control

DHW / BOILER SUMMARY

System Name	System Type	Distribution Type	Qty.	Rated Input	Vol. (Gals.)	Energy Factor or Recovery Efficiency	Standby Loss or Pilot	TANK INSUL. External R-Val

CENTRAL SYSTEM RATINGS

			HEATING			COOLING			
System Name	System Type	Qty.	Output	Aux. kW	Efficiency	Output	Sensible	Efficiency	Economizer Type

CENTRAL FAN SUMMARY

			SUPPLY FAN				RETURN FAN			
System Name	Fan Type	Motor Location	CFM	BHP	Motor Eff.	Drive Eff.	CFM	BHP	Motor Eff.	Drive Eff.

MECHANICAL EQUIPMENT SUMMARY (Part 2 of 2) MECH-2

PROJECT NAME	DATE

VAV SUMMARY

Zone Name	VAV					FAN					BASEBOARD	
	System Type	Qty.	Min. CFM Ratio	Reheat? Type	ΔT	Flow Ratio	CFM	BHP	Motor Eff.	Drive Eff.	Type	Output

EXHAUST FAN SUMMARY

EXHAUST FAN						EXHAUST FAN					
Room Name	Qty.	CFM	BHP	Motor Eff.	Drive Eff.	Room Name	Qty.	CFM	BHP	Motor Eff.	Drive Eff.

4.3.3 MECH-3: Mechanical Ventilation

This form is used to document the design outdoor ventilation rate for each space, and the total amount of outdoor air that will be provided by the space-conditioning or ventilating system. For VAV systems, this form also documents the reduced cfm to which each VAV box must control before allowing reheat.

One copy of this form should be provided for each mechanical system. Additional copies may be required for systems with a large number of spaces or zones. In lieu of this form, the required outdoor ventilation rates and airflows may be shown on the plans.

Note that, in all of the calculations that compare a supply quantity to the REQ'D O.A. quantity, the actual percentage of outdoor air in the supply is ignored.

The design outdoor ventilation rate and air distribution assumptions made in the design of the ventilating system must be documented on the plans. Documentation must be in accordance with Section 10-103 of Title 24.

Areas in buildings for which natural ventilation is used should be clearly designated. Specifications must require that building operating instructions include explanations of the natural ventilation system.

A. Ventilation Calculations

1. **COLUMN A - ZONE/SYSTEM** is the system or zone identifier as shown on the plans.

2. **AREA BASIS -** outdoor air calculations are documented in Columns B, C and D. If a space is naturally ventilated, it should be noted here and the rest of the calculations (Columns B-K) skipped.

   COLUMN B - COND. AREA (SF) is the area in square feet for the SPACE, ZONE, or SYSTEM identified in Column A.

   COLUMN C - CFM PER SF is the minimum allowed outdoor ventilation rate as specified in Table No. 1-F of the *Standards* for the type of use listed.

   COLUMN D - MIN CFM is the minimum ventilation rate calculated by multiplying the COND. AREA in Column B by the CFM PER SF in Column C.

3. **OCCUPANCY BASIS** outdoor air calculations are calculated in Columns E, F and G.

   COLUMN E - NO. OF PEOPLE is determined using one of the methods described in Section 4.2.1.F.

   COLUMN F - CFM PER PERSON is determined using one of the methods described in Section 4.2.1.F.

   COLUMN G - MIN CFM is the NO. OF PEOPLE multiplied by CFM PER PERSON.

4. **COLUMN H - REQ'D O.A.** is the larger of the outdoor ventilation rates calculated on an AREA BASIS or OCCUPANCY BASIS (Column D or G).

5. **COLUMN I - DESIGN OUTDOOR AIR CFM** is the actual outdoor air quantity to be provided based on cooling loads. If this quantity is less than the REQ'D O.A., then TRANSFER AIR (Column K) will have to make up the difference.

6. **VAV MIN. CFM** calculations are made for variable air volume systems only, in Column J.

   COLUMN J - VAV MIN. CFM is the maximum airflow to which the VAV box supply must be reduced before reheat is permitted. It is calculated as the largest of:

   a. design fan supply cfm (MECH-2, Part 2) x 30%; or

   b. cond. area (sf) x 0.4 cfm/sf; or

   c. 300 cfm

7. **COLUMN K - TRANSFER AIR** is the amount of air that must be directly transferred from another space so that the space supply is always no less than REQ'D O.A. It is calculated as the largest of:

   a. REQ'D O.A. - DESIGN Outdoor Air (Column H - I); or

   b. REQ'D O.A. - VAV MIN. CFM for a VAV system (Column H - J); or

   c. 300 cfm

   In these calculations, the actual percentage of outside air in the supply is ignored.

TOTALS are summed for

a. **NO. OF PEOPLE** - This value should match the number people used in the load calculations as summarized in the SIZING AND EQUIPMENT SELECTION on MECH-4.

b. **REQ'D O.A.** - The values listed for the system on MECH-1 Design OUTDOOR AIR CFM be at least this amount. The designer may elect to use a greater amount of outdoor air judged necessary to ensure indoor air quality.

c. **DESIGN OUTDOOR AIR** - This value should match any amounts listed for cooling equipment sizing on MECH-4 CFM.

B. Sample Form: MECH-3 Mechanical Ventilation

MECHANICAL VENTILATION MECH-3

PROJECT NAME	DATE

MECHANICAL VENTILATION

A	B	C	D	E	F	G	H	I	J	K
	AREA BASIS			OCCUPANCY BASIS			REQ'D. O.A. (MAX. OF D OR G)	DESIGN OUTDOOR AIR CFM	VAV MIN. CFM	TRANSFER AIR CFM
ZONE/ SYSTEM	COND AREA (SF)	CFM PER SF	MIN. CFM (B X C)	NO. OF PEOPLE	CFM PER PERSON	MIN. CFM (E X F)				
	Totals (For MECH-4)									

- **C** Minimum ventilation rate per Section § 121, Table 1-F.
- **E** Based on expected number of occupants or at least 50% of Chapter 10 1997 UBC occupant density
- **I** Must be greater than or equal to H, or use Transfer Air. Design outdoor air includes ventilation from supply air system & exhaust fans which Operate at design conditions.
- **K** Must be greater than or equal to (H - I), and, for VAV, greater than or equal to (H - J).

4.3.4 MECH-4: Mechanical Sizing and Fan Power

This form is used to document the calculations used in sizing equipment and demonstrating compliance with the fan power requirements when using the Prescriptive Approach. The PROJECT NAME, DATE, SYSTEM NAME and FLOOR AREA served by this system should be entered at the top of the form. One form should be provided for each space-conditioning system.

A. Sizing and Equipment Selection

Separate columns are provided for heating and cooling load documentation. The actual load calculations should not be submitted with this form unless requested by the Building Department.

1. **DESIGN CONDITIONS** documents the outdoor and indoor temperature and humidity conditions used in the load calculations. These temperatures should be taken from ASHRAE publication SPCDX for the building location as described in Section 4.2.2B and found in Appendix C.

   OUTDOOR DRY BULB TEMPERATURE for cooling must be no greater than listed in the Summer Design Dry Bulb 0.5% column. Heating should be no less than the temperature listed in the Winter Median of Extremes.

   OUTDOOR WET BULB TEMPERATURE for cooling must be no greater than the Summer Design Wet Bulb 0.5% column. The heating entry is not used.

   INDOOR DRY BULB TEMPERATURE must be determined in accordance with ANSI/ASHRAE 55-1992, or Chapter 8 of the *ASHRAE Handbook, 1993 Fundamentals Volume*. Winter humidification and summer dehumidification are not required.

2. **SIZING** summarizes the major categories of building loads, as determined by the designer in the load calculations, based on the design conditions.

DESIGN OUTDOOR AIR lists the design outdoor quantity determined on form MECH-3, Column I and the corresponding heating and cooling loads. The design outdoor air in Kbtu/h must be calculated in accordance with the procedures described in Chapter 8 of the ASHRAE Handbook, 1993 Fundamentals. The calculations may be done by hand or by a computer program. To calculate use the following equation for cooling and heating as follows:

$$(\Delta T \times DOA \times 1.08) \quad \text{in } \frac{BTU\text{-}^{o}F}{HR}$$

Where;

ΔT = Temperature change between dry bulb and indoor dry bulb temperature for cooling and heating on MECH-4 in ^{o}F.

DOA = Design Outside Air (From MECH-3, Column I) in CFM

1.08 = Conversion factor from CFM to KBTU/Hr.

ENVELOPE LOAD summarizes the heat gains and losses through the building envelope, including conduction, solar radiation and infiltration. These loads must be determined using the surface areas and envelope characteristics as documented on form ENV-2, Part 2 of 5, Column E.

The envelope load in kBtu/h must be calculated in accordance with the procedures described in Chapter 8 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done as follows:

$$UA \times \Delta T \text{ in } \frac{BTU\text{-}^{o}F}{HR}$$

Where:

U = U-Value of ech proposed assembly in BTU/Hr – SF.

A = Surface area of each proposed assembly in SF.

ΔT = Temperature change between dry bulb and indoor dry bulb temperature for cooling and heating on MECH- 4 in ^{o}F.

LIGHTING lists the average Watt/sf power density for the spaces served by this system, as documented on form LTG-2, Adjusted Actual Watts. The calculations may be made by taking. The cooling loads for lighting in kBtu/h must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by hand (watts/sf x 3.41) or by a computer program which uses these procedures. Lighting is disregarded for heating calculations.

PEOPLE lists the number of people as documented on Form MECH-3, and the cooling loads based on the expected activities. The cooling loads for people in kBtu/h must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by hand or by a computer program which uses these procedures. People loads are disregarded for heating calculations.

MISCELLANEOUS EQUIPMENT lists the average Watts/sf power density for miscellaneous equipment that contributes to cooling loads. The cooling loads for miscellaneous equipment in kBtu/h must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by (watts/sf x 3.41) or by a computer program. Equipment loads are disregarded for heating calculations.

OTHER lists any other loads, such as process loads, duct loss and infiltration. The amount should be listed, and the load described. The miscellaneous equipment loads in kBtu/h must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by hand or by a computer program which uses these procedures.This space should also be used for documenting latent loads that are used in selecting the equipment if the selection is based on latent load, rather than sensible load.

OTHER LOADS and SAFETY FACTOR. The designer is allowed to increase the cooling load by 10 percent and the heating load by 30 percent to account for “Other Loads” such as warm-up and cool-down. The designer is also allowed to increase both heating and cooling loads by an additional 10 percent “Safety Factor” to account for unexpected loads. Therefore, the maximum allowed overall factor is (1.10×1.10) or 1.21 for cooling, and (1.10×1.30) or 1.43 for heating.

3. **SELECTION** summarizes how the load calculations are used to select the equipment size

   MAXIMUM ADJUSTED LOAD is the cooling and heating loads, adjusted by Other Loads and the Safety Factor. This is usually the sensible load unless latent loads were used in the equipment selection. If latent loads were used, this entry should be the total sensible and latent load.

   INSTALLED EQUIPMENT CAPACITY lists the cooling and heating capacity of the equipment at the design conditions. If the equipment selection is based on sensible load only, the sensible capacity of the equipment is listed here. If equipment selection is based on total load, the total load should be listed here. If the installed capacity is larger than the maximum adjusted load, the designer should explain the exception taken.

B. Fan Power Consumption

This section is used to show how the fans associated with the space-conditioning system comply with the maximum fan power requirements. All supply, return, exhaust fans, and space exhaust fans – such as toilet exhausts – in the space-conditioning system that operate during the peak design period must be listed. Included are supply/return/exhaust fans in packaged equipment. Economizer fans that do not operate at peak are excluded. Also excluded are all fans that are manually switched and all fans that are not directly associated with moving conditioned air to/from the space-conditioning system, such as condenser fans and cooling tower fans.

If the total horsepower of all fans in the system is less than 25 HP, then this should be noted in the **FAN DESCRIPTION** column and the rest of this section left blank. If the total system horsepower is not obvious, such as when a VAV system has many fan-powered boxes, then this section must be completed.

1. **COLUMN A - FAN DESCRIPTION** lists the equipment tag or other name associated with each fan.

2. **COLUMN B - DESIGN BRAKE HORSEPOWER** lists the brake horsepower, excluding drive losses, as determined from manufacturer's data.

   For dual-fan, dual-duct systems, the heating fan horsepower may be the (reduced) horsepower at the time of the cooling peak. If unknown, it may be assumed to be 35 percent of design. If this fan will be shut down during the cooling peak, enter 0 in Column B.

   If the system has fan-powered VAV boxes, the VAV box power must be included if these fans run during the cooling peak. The power of all boxes may be summed and listed on a single line. If the manufacturer lists power consumption in watts, then the wattage sum may be entered directly in Column F. Horsepower must still be entered in Column B if the designer intends to show that total system has less than 25 HP.

3. **COLUMNS C & D - EFFICIENCY** lists the efficiency of the **MOTOR** and **DRIVE**. The default for a direct drive is 1.0; belt drive is 0.97. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

4. **COLUMN E - NUMBER OF FANS** lists the number of identical fans included in this line.

   COLUMN F - PEAK WATTS is calculated as:

   $(BHP \times Number \times 746W/HP)(E_m \times E_d)$

   where E_m and E_d are the efficiency of the motor and the drive, respectively.

5. **COLUMN G - CFM** is the design supply airflow at the cooling peak. This field is left blank for return fans, exhaust fans, or other fans that do not add to the net air supply to a space. (Note that power consumption for returns and exhausts is accounted for in Column B).

   For dual-duct systems, the airflow must include the hot deck airflow at the time of the cooling peak. For VAV systems with fan powered boxes, the airflow of the box fan may or may not be allowable depending on the configuration (see Section 4.2.2C).

6. **TOTALS** are provided for both PEAK WATTS (Column F) and CFM (Column G).

7. **TOTAL FAN SYSTEM POWER DEMAND, WATTS/CFM** is calculated by dividing the total PEAK WATTS (Column F) by the total CFM (Column G). To comply, total space-conditioning system power demands must not exceed 0.8 W/cfm for constant volume systems, or 1.25 W/cfm for VAV systems.

C. Sample Form: MECH-4 Mechanical Sizing and Fan Power

MECHANICAL SIZING AND FAN POWER — MECH-4

PROJECT NAME	DATE
SYSTEM NAME	FLOOR AREA

NOTE: Provide one copy of this form for each mechanical system when using the Prescriptive Approach.

SIZING and EQUIPMENT SELECTION

1. DESIGN CONDITIONS:			**COOLING**	**HEATING**
- OUTDOOR, DRY BULB TEMPERATURE		(APPENDIX C)		
- OUTDOOR, WET BULB TEMPERATURE		(APPENDIX C)		
- INDOOR, DRY BULB TEMPERATURE		(See Chap. 8, ASHRAE handbook, 1993)		
2. SIZING				
- DESIGN OUTDOOR AIR		CFM (MECH 3; COLUMN I)		
- ENVELOPE LOAD		Btu/Hr (ENV-2 Part 2 of 5 Column E)		
- LIGHTING		W / SF (Adjusted Actual Watts-LTG-2)		
- PEOPLE		# OF PEOPLE (MECH 3; COLUMN E)		
- MISCELLANEOUS EQUIPMENT		WATTS / SF		
- OTHER				
1)				
2)				
3)				
		TOTALS		
OTHER LOADS/SAFETY FACTOR (1.21 for cooling, 1.43 for heating)				
MAXIMUM ADJUSTED LOAD (TOTALS FROM ABOVE x OTHER LOAD SAFETY FACTOR)				

3. SELECTION:

	COOLING	HEATING
INSTALLED EQUIPMENT CAPACITY	KBtu / Hr	KBtu / Hr

IF INSTALLED CAPACITY EXCEEDS MAXIMUM ADJUSTED LOAD, EXPLAIN ______________________

FAN POWER CONSUMPTION

A	B	C	D	E	F	G
FAN DESCRIPTION	**DESIGN BRAKE HP**	**EFFICIENCY** MOTOR	**EFFICIENCY** DRIVE	**NUMBER OF FANS**	**PEAK WATTS** B x E x 746 / (C x D)	**CFM** (Supply Fans)
				TOTALS		

NOTE: Include only fan systems exceeding 25 HP (see § 144). Total Fan System Power Demand may not exceed 0.8 Watts/CFM for constant volume systems or 1.25 Watts/CFM for VAV systems.

TOTAL FAN SYSTEM POWER DEMAND WATTS / CFM ____ Col. F / Col. G

4.4 MECHANICAL INSPECTION

The mechanical building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the MECH-1 Certificate of Compliance form printed on the plans (See Section 4.3.1). Included on the MECH-1 are "Notes to Field" that are provided by the plan checker to alert the inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I.

Chapter 4 Index

A

AFUE · 3, 4, 9, 65
Agricultural · 59, 60
Air Balance · 65
Air Delivery Systems · 6
Air Economizer · 6, 7
Air Mixing · 1, 6
Airflow · 11
Alterations · 1, 42
Alternative Calculation Methods Approval Manual · 42
Annual Fuel Utilization Efficiency · 3
Apartments · 13, 14
Appliance Efficiency Regulations · 3, 4, 9, 10, 62
Application · 1, 42
Arcades · 14
Area · 2, 13, 14
Arenas · 14
ARI · 9, 64
ASHRAE 62-1989 · 15
ASHRAE Handbook · 29, 30, 32, 33, 78, 79
Assembly · 13, 14
Associated Air Balance Council · 20, 62
Attics · 1, 6
Auditoriums · 13, 14
Automatic Time · 23

B

Balancing · 17, 20, 62
Bank/Financial Institution · 14
Bars · 11, 14
Basements · 13
Beauty Shops · 14
Boilers · 69
Building · 12, 13, 15, 20, 78
Building Department · 78
Business and Professions Code · 59

C

California Code of Regulations · 9, 59
California Safety Code · 20, 62
Central Plant · 26, 54, 55
Certificate of Compliance · 57, 59, 66, 67, 68, 82
Changeover Systems · 19
Churches · 13, 14
Circulating Systems · 30
Classroom · 15
Climate · 42
Coefficient of Performance · 3
Combustion Efficiency · 3, 9
Commercial · 11, 13, 14
Compliance · 1, 9, 10, 42
Components · 1, 42
Computer · 1, 34, 42
Computer Method · 1, 42
Concepts · 39
Conference Rooms · 14
Constant Volume · 6
Contaminants · 1
Control Equipment Certification · 10
Controls · 1, 3, 9, 10, 17, 21, 24, 29, 32, 37, 40, 61, 62
Convention · 14
Cooling · 3, 33, 52, 64
Corridors · 14

D

Dampers · 20, 24, 53, 55
DATE OF PLANS · 58
Definitions of Efficiency · 1, 3
Demand Control Ventilation · 1, 8, 19
Dining Rooms · 13, 14
Direct Air Transfer · 16
Distribution of Outdoor Air · 16
Documentation · 59, 75
Documentation Author · 59
Duct Insulation · 29
Ducts · 1, 9, 28, 45, 48, 51, 55, 57

E

Economizer · 7, 8, 39, 79
Electric Resistance · 1
Energy Efficiency Ratio · 4
Energy Factor · 4
ENV-1 · 58
ENV-2 · 78
Equipment Certification · 1, 9
Equipment Schedules · 69
Equipment Sizing · 32
Exhaust Air · 5

F

Fan Coils · 24
Fan Cycling · 19
Fan Power · 1, 4, 34, 37, 51, 57, 78, 79, 80, 81
Fan Power Consumption · 1, 34, 79

Field-Fabricated · 28
Fire and Life Safety · 26
Floors · 13, 14

G

Garages · 59, 60
Gas Furnace · 43, 65
Guest Room · 14, 22

H

Heat Pump · 41, 43, 52, 55, 62, 70
Heating · 1, 3, 9, 20, 31, 33, 41, 43, 44, 46, 47, 50, 52, 53, 55, 57, 64, 78
High-Rise Residential · 22
Hotel Function Area · 14
Hotel Lobby · 14
Hotel/Motel · 22

I

Industrial · 14
Inspection · 1, 2, 82
Installation · 28
Insulation · 1, 27, 28
Integrated Part Load Value · 4
Isolation Area Devices · 25
Isolation of Central Air Systems · 25
Isolation Zones · 25

K

Kitchens · 13

L

Lavatories · 30, 63
Lighting · 33, 79
Load Calculations · 1, 32
LTG-2 · 79

M

Malls · 13, 14
Mandatory Measures · 1, 8, 60
Manufacturers · 10
MECH-1 · 1, 57, 66, 67, 68, 76, 82
MECH-2 · 1, 57, 65, 69, 72, 73, 74, 75
MECH-3 · 1, 57, 65, 75, 76, 77, 78, 79
MECH-4 · 1, 57, 69, 70, 71, 72, 76, 78, 80, 81
Mechanical Compliance Approaches · 2
Mechanical Concepts · 1, 3
Mechanical Equipment · 13, 14, 57, 69, 70, 72, 73, 74
Mechanical Equipment Summary · 57, 69, 72, 73, 74
Mechanical Mandatory Measures · 60, 61
Mechanical Systems · 1
Mechanical Ventilation · 1, 12, 57, 75, 76, 77
Medical · 14
Mixed Air · 5
Modeling · 1, 42

N

National Electric Code · 31
National Environmental Balancing Bureau · 20, 62
Natural Ventilation · 1, 11, 18, 65
Notes to Field · 82
Nurseries · 14

O

Occupancy · 10, 14, 18, 23, 42, 64
Occupancy Sensors · 10
Offices · 13, 14, 19
Optimized Start · 19
Orientation · 42
Outdoor Air · 5, 33, 76
Outdoor Ventilation · 1, 10, 16
Outside Air Certification · 20, 62, 65
Outside Air Measurement · 20, 62

P

Packaged Air Conditioner · 43
Performance Approach · 1, 41
PHASE OF CONSTRUCTION · 58
Pilot Lights · 1, 9, 10
Pipe Insulation · 9, 26, 27
Plenum · 6, 28, 66
Pool · 1, 9, 10, 13, 14, 31, 63
Prescriptive Approach · 1, 31, 70, 71, 72, 78
Pressure Dependent · 6
Pressure Independent · 6
Purge · 18, 25

R

Recooling · 6, 37
Refrigeration · 9, 64

Reheating · 37
Repair · 14
Retail · 13, 14
Return Air · 5, 6
R-value · 26, 30, 63, 66, 70

S

Safety Factor · 79
Seasonal Energy Efficiency Ratio · 4
Service Water Heating · 1, 9, 30, 41, 62
Setback · 22, 24
Shut-off · 21, 22
Smoking Lounges · 14
Sources of Contaminants · 8
Space Conditioning · 4, 5, 9, 21, 37
Space Conditioning System · 5, 9, 21
Space Conditioning Zone · 37
Specifications · 75
State Building · 31
Statement of Compliance · 59
Storage Tank Insulation · 30
Summer Design Dry Bulb · 23, 33, 78
Summer Design Wet Bulb · 33, 78
Supply Air · 5, 12, 40
Supply Air Reset · 40
Swimming Pool · 13, 14

T

Theaters · 14
Thermal Efficiency · 4, 9
Thermostats · 2, 21, 22, 62
Time Control · 24
Transfer Air · 6
Types of Air · 1, 5
Typical Building Energy Use · 2

U

UBC · 12, 13, 14

V

Variable Air Volume · 6, 19, 35
VAV Box · 6
VAV Systems · 16
Ventilation · 1, 2, 9, 10, 12, 14, 15, 16, 19, 20, 33, 43, 44, 46, 49, 51, 52, 53, 54, 55, 56, 62, 75
Ventilation Rate · 12, 14, 19
Ventilation System Operation and Controls · 16

W

Warehouses · 13, 14
Water Heaters · 31, 69
Wholesale · 14

Z

Zonal Systems · 25
Zone Controls · 1, 38, 44, 46, 49, 52, 53, 54, 56
Zone Reheat · 1, 6
Zone Thermostatic Control · 21

LTG

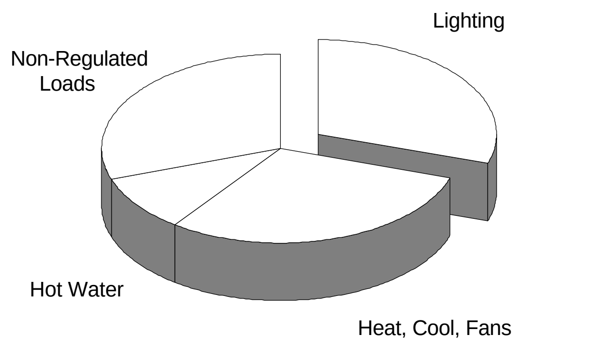
Chapter 5: Lighting Systems

5.0 CHAPTER OVERVIEW

This chapter covers the *Energy Efficiency Standards* that affect lighting design and installation, including lighting controls. It is addressed primarily to lighting designers or electrical engineers and to building department personnel responsible for lighting and electrical plan checking and inspection. Additional information is found in Chapter 2: Scope and Application, and in Chapter 6: Special Topics.

Chapter Contents

5.0 Chapter Overview	**5-1**
5.1 Introduction	**5-2**
5.1.1 Lighting Compliance Approaches	5-2
5.1.2 Basic Lighting Concepts and Definitions	5-3
A. Lighting Trade-Offs	5-3
B. Definitions	5-4
C. Occupancy Type	5-7
D. Lighting Controls	5-9
5.2 Lighting Design Procedures	**5-10**
5.2.1 Mandatory Measures	5-10
A. Area Controls	5-10
B. Bi-Level Switching	5-11
C. Daylit Areas	5-11
D. Shut-Off Controls	5-16
E. Display Lighting	5-18
F. Exterior Lights	5-18
G. Tandem Wiring	5-18
H. Certified Automatic Lighting Control Devices	5-18
I. Certified Ballasts and Luminaires	5-20
J. High Rise Residential Living Quarters & Hotel/ Motel Guest Rooms	5-21
5.2.2 Prescriptive Approach	5-24
A. Complete Building Method	5-24
B. Area Category Method	5-25
C. Tailored Method	5-28
D. Simplification for Tenant Spaces	5-36
E. Summary	5-36
5.2.3 Performance Approach	5-40
5.2.4 Actual Lighting Power	5-40
A. Exempt Lighting	5-40
B. Actual Lighting Power Calculations	5-41
C. Automatic Lighting Control Credits	5-43
5.2.5 Alterations	5-43
5.3 Lighting Plan Check Documents	**5-46**
5.3.1 LTG-1: Certificate of Compliance	5-46
A. LTG-1 Part 1 of 2	5-46
B. LTG-1 Part 2 of 2	5-51
C. Sample Form: LTG-1	5-52
5.3.2 LTG-2: Lighting Compliance Summary	5-54
A. Actual Lighting Power	5-54
B. Allowed Lighting Power	5-54
C. Sample Form: LTG-2	5-56
5.3.3 LTG-3: Lighting Controls Credit Worksheet	5-57
A. Sample Forms: LTG-3	5-58
5.3.4 LTG-4: Tailored LPD Summary and Worksheet	5-59
A. LTG-4: Part 1 of 3	5-59
B. LTG-4: Part 2 of 3	5-60
C. LTG-4: Part 3 of 3	5-61
D. Sample Form: LTG-4	5-64
5.3.5 LTG-5: Room Cavity Ratio Worksheet (≥ 3.5)	5-67
A. Rectangular Spaces	5-67
B. NonRectangular Spaces	5-67
C. Sample Form: LTG-5	5-68
5.4 Lighting Inspection	**5-69**



Energy Efficiency Report, October, 1990, California Energy Commission Publication No. 400-90-003

Figure 5-1: Lighting Energy Use
Lighting accounts for 29% of all commercial building electricity use in California.

The Introduction section (5.1) explains the alternative compliance approaches for lighting and introduces the basic lighting concepts necessary to understand the requirements. The Lighting Design Procedures section (5.2) covers the mandatory, prescriptive, and performance requirements for the lighting systems. For the convenience of designers, a summary of the most important requirements for design and layout of the lighting and control concepts is included. The Lighting Plan Check Documents section (5.3) describes the information that must be included in the building plans to show compliance with the *Standards*. The compliance forms are presented and discussed. The Lighting Inspection section (5.4) refers to the Inspection Checklist in Appendix I identifying the items that the inspector will verify in the field.

5.1 INTRODUCTION

Lighting is one of the single largest consumers of energy (kilowatt-hours) in a commercial building (Figure 5-1). The effective reduction of this energy use, without compromising the quality of lighting or task work, is the objective of the lighting energy standards. These *Standards* are the result of the involvement of many representatives of the lighting design and manufacturing community, and of building departments across the state. A great deal of effort has been devoted to making the lighting requirements practical and realistic. This chapter summarizes those requirements and the approaches to complying with them.

5.1.1 Lighting Compliance Approaches

The primary mechanism for regulating lighting energy under the *Standards* is to limit the allowable lighting power (watts) installed in the building. Other mechanisms require basic equipment efficiency, and require that the lighting is controlled to permit efficient operation.

MANDATORY MEASURES apply to all lighting systems and equipment (Sections 119, 130, 131 and 132). These requirements may include manual switching, daylit area switching, automatic shut-off controls, and tandem wiring for ballasts. The mandatory requirements must be met under either the prescriptive or performance approach.

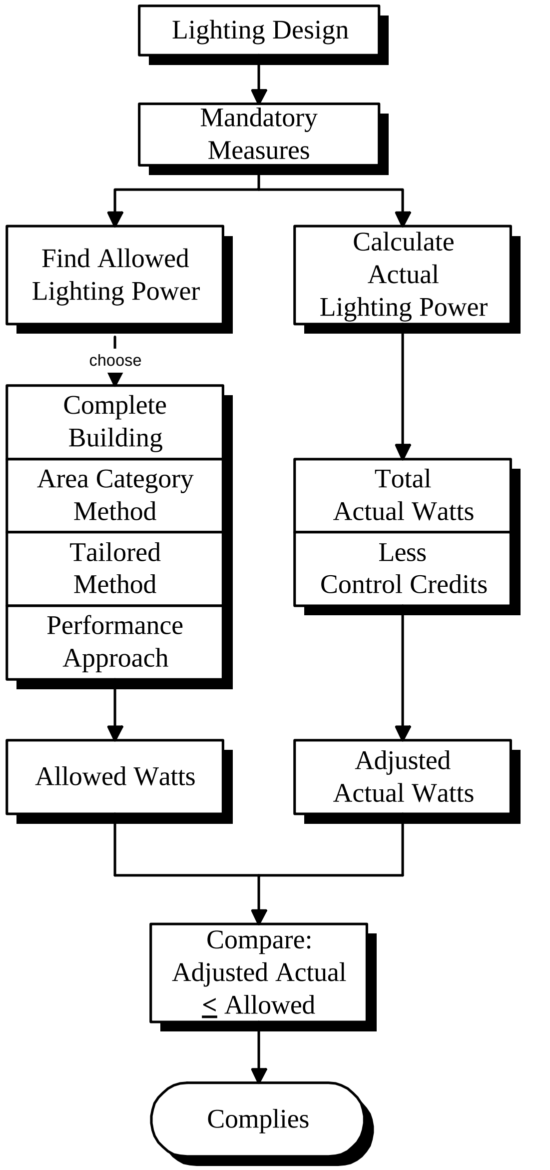
ALLOWED LIGHTING POWER for a building is determined by one of four methods:

Complete Building Method: applicable when the entire building's lighting system is designed and permitted at one time. In some cases the Complete Building Method may be used for an entire tenant space in a multi-tenant building. A single lighting power value governs the entire building (Section 146(b)1). See Section 5.2.2A for other applications of the complete building method. See Section 5.1.2A and Appendix G for definition of Entire Building.

Area Category Method: applicable for any permit situation, including tenant improvements. Lighting power values are assigned to each of the major function areas of a building (offices, lobbies, corridors, etc.) (Section 146(b)2).

Tailored Method: applicable when additional flexibility is needed to accommodate special task lighting needs. Lighting power allowances are determined room-by-room and task-by-task (Section 146(b)3).

Figure 5-2: Lighting Compliance Flowchart



Performance Approach: applicable when the designer uses an approved computer program to demonstrate that the lighting power in the proposed design meets the energy budget. The performance approach requires the use of an Energy Commission certified computer program and may only be used to model the performance of lighting systems that are covered under the building permit application (see section 5.2.3).

ACTUAL LIGHTING POWER (ADJUSTED) is based on total design wattage of lighting, less adjustments for any lighting control credits taken for non-mandatory controls, such as occupant-sensing devices, lumen maintenance controls, or automatic daylighting controls (Section 146(a)).

The Actual Lighting Power (Adjusted) must not exceed the Allowed Lighting Power for the lighting system to comply.

5.1.2 Basic Lighting Concepts and Definitions

This section includes key concepts and definitions from the *Standards* that apply to the lighting and control systems.

A. Lighting Trade-offs

The *Standards* restrict the overall installed lighting power in the building, regardless of the compliance approach. However, there is no general restriction regarding where or how general lighting power is used. This means that installed lighting may be greater than the *Standards* allowances in some areas of the building and lower in others, as long as the total does not exceed the Allowed Lighting Power.

Example 5-1: Lighting Trade-Offs: General Lighting

Question

Under the Area Category Method, a mixed use building is determined to have an allowed lighting power of 23,500 watts. As part of this determination, an office area within the building is found to have an allowance of 1.6 watts/ft^2. One of the private offices within this area is designed with an actual lighting power density of 2.0 watts/ft^2. Is this permitted?

Answer

Yes. Provided the actual lighting power of the entire building does not exceed the 23,500 watt limit, there is no limit on the individual office.

This is true for general lighting no matter what method is used to determine the allowed lighting power.

Note that in Examples 5-1 and 5-2, it is not necessary to specify precisely where the watts come from when a trade-off occurs. These details are not needed for compliance; any individual trade-offs are included in the totals. It is necessary only to demonstrate that the actual watts total for the building does not exceed the total allowable. Trade-offs are not allowed with so-called use it or lose it categories of lighting. These are specific task or display lighting applications, such as chandeliers under the Area Category Method (Section 5.2.2B) or display lighting under the Tailored Method (Section 5.2.2C), where the allowable lighting power for the application is determined from:

1. wattage allowance specified by the *Standards*

2. actual wattage of the fixture(s) assigned to the application

For *use it or lose it* applications, the allowable lighting power is the lesser of these two wattages. This means that the actual wattage is lower than the allowance. Both the remaining watts in the allowance and the actual wattage are not available for trade-off to other areas of the building.

Example 5-2: Lighting Trade-offs: Display Lighting Part 1

Question

A display lighting application (one of the "use it or lose it" applications) is determined to have a lighting power allowance of 350 watts. The actual luminaires specified for the display total 300 watts. How does this affect the allowed watts and the actual watts (adjusted if applicable) for the building?

Answer

The lower value, 300 watts, is shown as total allowed watts for the building. The actual lighting power is also 300 watts. There are no watts available for use through trade-offs elsewhere in the building.

Example 5-2: Lighting Trade-offs: Display Lighting Part 2

Question

A display lighting application is determined to have a lighting power allowance of 500 watts. The actual luminaires specified for the display total 600 watts. How does this affect the allowed watts and the actual watts (adjusted if applicable) for the building?

Answer

As before, the lower value, 500 watts in this case, is shown as the total allowed watts for the display. The proposed lighting power will include the full 600 watts. For the building lighting to comply, the extra 100 watts used by the display fixtures must be eliminated from elsewhere in the building.

Lighting control credits reduce the actual installed watts, making it easier to meet the allowed watts. This can have the same effect as trade-offs.

The specific calculations involved in the trade-offs discussed in this section are carried out on the compliance forms presented in Section 5.3.

There is another type of lighting trade-off available under the *Standards*. This is the ability to make trade-offs under the performance approach between the lighting system and the envelope or mechanical systems. Trade-offs can only be made when permit applications are sought for those systems involved, and where the trade-off has the effect of altering the Allowed Lighting Power for the building. When a Lighting Power Allowance is calculated using the performance approach, the allowance is treated exactly the same as an allowance determined using one of the other compliance methods.

B. Definitions

Included in this section are definitions of terms other than occupancy type and terms specific to controls that have application to compliance with the lighting requirements of the *Standards*.

Accessible is having access thereto, but which first may require removal or opening of access panels, doors, or similar obstructions.

Annunciated is a visual signaling device that indicates the on, off, or other status of a load.

Chandeliers (see Ornamental Chandelier)

Complete Building is an entire building with one occupancy making up 90 percent of the conditioned floor area (see also Entire Building).

Daylit Area is the space on the floor that is the larger of (a) plus (b), or (c);

(a) For areas daylit by vertical glazing, the daylit area has a length of 15 feet, or the distance on the floor, perpendicular to the glazing, to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side, the distance to an opaque partition, or one-half the distance to the closest skylight or vertical glazing, whichever is least.

(b) For areas daylit by horizontal glazing, the daylit area is the footprint of the skylight plus, in each of the lateral and longitudinal dimensions of the skylight, the lesser of the floor-to-ceiling height, the distance to the nearest 60-inch or higher opaque partition, or one-half the horizontal distance to the edge of the closest skylight or vertical glazing.

(c) The daylit area calculated using a method approved by the Energy Commission.

Display Lighting is lighting confined to the area of a display that provides a higher level of illuminance than the level of surrounding ambient illuminance.

Display, Public Area are areas for the display of artwork, theme displays, and architectural surfaces in dining and other areas of public access, excluding restrooms and separate banquet rooms.

Display, Sales Feature is an item or items that requires special highlighting to visually attract attention and that is visually set apart from the surrounding area.

Display, Sales Feature Floor is a feature display in a retail store, wholesale store, or showroom that requires display lighting.

Display, Sales Feature Wall are the wall display areas, in a retail or wholesale space, that are in the vertical plane of permanent walls or partitions, and that are open shelving feature displays or faces of internally illuminated transparent feature display cases within the Gross Sales Wall Area.

Effective Aperture (EA) is (1) for windows, the visible light transmittance (VLT) times the window wall ratio; and (2) for skylights, the well index times the VLT times the skylight area times 0.85 divided by the gross exterior roof area.

Efficacy is the ratio of light from a lamp to the electrical power consumed (including ballast losses), expressed in lumens per watt.

Entire Building is the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all existing conditioned and unconditioned space within the structure.

High Bay is a space with luminaires 25 feet or more above the floor.

Low Bay is a space with luminaires less than 25 feet above the floor.

Luminaire is a complete lighting unit consisting of a lamp and the parts designed to distribute the light, to position and protect the lamp, and to connect the lamp to the power supply; commonly referred to as "lighting fixtures" or "instruments."

Newly Conditioned Space is any space being converted from unconditioned to directly conditioned or indirectly conditioned space, or any space being converted from semi-conditioned to directly conditioned or indirectly conditioned space. Newly conditioned space must comply with the requirements for an addition. See Section 149 for nonresidential occupancies and Section 152 for residential occupancies.

Ornamental Chandelier are ceiling-mounted, close-to-ceiling, or suspended decorative luminaires that use glass, crystal, ornamental metals, or other decorative material and that typically are used in hotel/motels, restaurants, or churches as a significant element in the interior architecture.

Poor Quality Lighting Tasks are visual tasks that require illuminance category "E" or greater, because of the choice of a writing or printing method that produces characters that are of small size or lower contrast than good quality alternatives that are regularly used in offices.

Private Office or Work Area is an office bounded by 30-inch or higher partitions and is no more than 200 square feet.

Primary Function Area is one of the categories listed in Table 5-4.

Public Areas are spaces generally open to the public at large, customers, congregation members, or similar spaces, where occupants need to be prevented from controlling lights for safety, security, or business reasons.

Readily Accessible is capable of being reached quickly for operation, repair, or inspection, without requiring climbing or removing obstacles, or resorting to access equipment.

Reduced Flicker Operation is the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation.

Room Cavity Ratio (RCR) is:

(a) for rectangular rooms; $\frac{5H\,(L + W)}{LW}$

or

(b) for irregular shaped rooms $\frac{2.5\,H \times P}{A}$

Where:

- L = Length of room
- W = Width of room
- H = Vertical distance from the work plane to the center line of the lighting fixture
- P = Perimeter of room
- A = Area of room

Sconce is a wall mounted decorative light fixture.

Skylight is glazing having a slope less than 60 degrees from the horizontal with conditioned space below, except for purposes of complying with Section 151(f), where a skylight is glazing having a slope not exceeding 4.76 degrees (1:12) from the horizontal.

Throw Distance is the distance between the luminaire and the center of the plane lit by the luminaire on a display.

Very Valuable Merchandise is rare or precious objects, including, but not limited to, jewelry, coins, small art objects, crystal, china, ceramics, or silver, the selling of which involves customer inspection of very fine detail from outside of a locked case.

Visible Light Transmittance (VLT) is the ratio (expressed as a decimal) of visible light that is transmitted through a glazing material to the light that strikes the material.

Well Index is the ratio of the amount of visible light leaving a skylight well to the amount of visible light entering the skylight well and is calculated as follows:

(a) for rectangular wells:

$$\left(\frac{\text{well height}(\text{well length} + \text{well width})}{2 \text{ X well length X well width}}\right)$$

or

(b) for irregular shaped wells:

$$\left(\frac{\text{WellHeight X WellPerimeter}}{\text{4 X WellArea}}\right)$$

Where the length, width, perimeter, and area are measured at the bottom of the well, and R (as used in Figure 5-7) is the weighted average reflectance of the walls of the well.

Window Wall Ratio is the ratio of window area to the exterior wall area, measured from floor to ceiling (this definition is unique to lighting applications).

Zone, Lighting is a space or group of spaces within a building that has sufficiently similar requirements so that lighting can be automatically controlled in unison throughout the zone by an illumination controlling device or devices, and does not exceed one floor.

C. Occupancy Type

The *Standards* recognize the fact that different building occupancies primary functions require different amounts of lighting power to provide adequate illumination for their various types of visual tasks. The allowed lighting power in the *Standards* depends on the occupancy.

Each of the occupancy primary function types listed may be used to determine the lighting power density (watts per square foot) for the Area Category Method (see Table 5-4). Some of these same primary function types can also use the Complete Building Method (see Table 5-3). The Standard definitions of the occupancy types are listed below.

- *Auditorium*: the part of a public building where an audience sits in fixed seating, or a room, area, or building with fixed seats used for public meetings or gatherings not specifically for the viewing of dramatic performances.

- *Auto Repair*: The portion of a building used to repair automotive equipment and/or vehicles, exchange parts, and may include work using an open flame or welding equipment.

- *Bank/Financial Institution*: An area in a public establishment used for conducting financial transactions including the custody, loan, exchange, or issue of money, for the extension of credit, and for facilitating the transmission of funds.

- *Classroom, Lecture, or Training*: A room or area where an audience or class receives instruction.

- *Commercial and Industrial Storage*: A room, area, or building used for storing items.

- *Convention, Conference, Multipurpose and Meeting Centers*: An assembly room, area, or building that is used for meetings, conventions and multiple purposes including, but not limited to, dramatic performances, and that has neither fixed seating nor fixed staging.

- *Corridor*: A passageway or route into which compartments or rooms open.

- *Dining*: A room or rooms in a restaurant or hotel/motel (other than guest rooms) where meals that are served to the customers will be consumed.

- *Electrical/Mechanical Room*: A room in which the building's electrical switchbox or control panels, and/or HVAC controls or equipment is located.

- *Exercise Center/Gymnasium*: A room or building equipped for gymnastics, exercise equipment, or indoor athletic activities.

- *Exhibit*: A room or area that is used for exhibitions that has neither fixed seating nor fixed staging.

- *General Commercial and Industrial Work*: A room, area, or building in which an art, craft, assembly or manufacturing operation is performed.

  High Bay: Luminaires 25 feet or more above the floor.

  Low Bay: Luminaires less than 25 feet above the floor.

- *Grocery Store*: A room, area, or building that has as its primary purpose the sale of foodstuffs requiring additional preparation prior to consumption.

- *Hotel Function Area*: A hotel room or area such as a hotel ballroom, meeting room, exhibit hall, or conference room, together with prefunction areas and other spaces ancillary to its function.

- *Hotel Lobby*: The contiguous spaces in a hotel/motel between the main entrance and the front desk, including waiting and seating areas, and other spaces encompassing the activities normal to a hotel lobby function.

- *Kitchen/Food Preparation*: A room or area with cooking facilities and/or an area where food is prepared.

- *Laundry*: A place where laundering activities occur.

- *Library*: A repository for literary materials, such as books, periodicals, newspapers, pamphlets and prints, kept for reading or reference.

- *Locker/Dressing Room*: A room or area for changing clothing, sometimes equipped with lockers.

- *Lounge/Recreation*: A room used for leisure activities which may be associated with a restaurant or bar.

- *Main Entry Lobby/Reception/Waiting*: The lobby of a building that is directly located by the main entrance of the building and includes the reception area, sitting areas, and public areas.

- *Malls, Arcades and Atria*: A public passageway or concourse that provides access to rows of stores or shops.

- *Medical and Clinical Care*: A room, area, or building that does not provide overnight patient care and that is used to promote the condition of being sound in body or mind through medical, dental, or psychological examination and treatment, including, but not limited to, laboratories and treatment facilities.

- *Museum*: A space in which works of artistic, historical, or scientific value are cared for and exhibited.

- *Office*: A room, area, or building of UBC group B occupancy other than restaurants.

- *Precision Commercial or Industrial Work*: A room, area, or building in which an art, craft, assembly or manufacturing operation is performed involving visual tasks of small size or fine detail such as electronic assembly, fine woodworking, metal lathe operation, fine hand painting and finishing, egg processing operations, or tasks of similar visual difficulty.

- *Reception/Waiting Area*: An area where customers or clients are greeted prior to conducting business.

- *Religious Worship*: A room, area, or building for worship.

- *Restaurant*: A room, area, or building that is a food establishment as defined in Section 27520 of the Health and Safety Code.

- *Restroom*: A room or suite of rooms providing personal facilities such as toilets and washbasins.

- *Retail And Sales*: A room, area, or building in which the primary activity is the sale of merchandise.

- *School*: A building or group of buildings that is predominately classrooms and that is used by an organization that provides instruction to students.

- *Stairs, Active/Inactive*: A series of steps providing passage from one level of a building to another.

- *Support Area*: A room or area used as a passageway, utility room, storage space, or other type of space associated with or secondary to the function of an occupancy that is listed in these regulations.

- *Theater, Motion Picture*: An assembly room, hall, or building with tiers of rising seats or steps for the showing of motion pictures.

- *Theater, Performance*: An assembly room, hall, or building with tiers of rising seats or steps for the viewing of dramatic performances, lectures, musical events and similar live performances.

- *Vocational Room*: A room used to provide training in a special skill to be pursued as a trade.

- *Wholesale Showroom*: A room where samples of merchandise are displayed.

D. Lighting Controls (§146(a)2)

Automatic lighting controls are an important part of the lighting requirements of the *Standards*. Some types of controls are necessary to comply with mandatory requirements (see Section 5.2.1A), while others allow designers the ability to reduce the Actual Lighting Power in their designs (see Section 5.2.4C). Several types of automatic lighting controls are required to be certified and listed by the Energy Commission (see Section 5.2.1D).

The following control device definitions are important for understanding the requirements of the *Standards* (Section 101).

Annunciated *is a visual signaling device that indicates the on, off, or other status of a load.* Annunciators are part of the requirements for such devices as area controls and automatic time switches when the area being controlled is not visible from the device location.

Automatic Time Switch Control Devices *are devices capable of automatically turning loads off and on based on time schedules.* There are many types of control devices that can perform this function.

NOTE: Some automatic time switch controls may incorporate "automatic off " and a "manual on" function such as hourly "off sweeps" after closing, or relay switches that drop out when power is interrupted. These devices would typically comply with the mandatory automatic shut-off provisions of Section 131(d).

Captive-Key Override *is a type of lighting control in which the key that activates the override cannot be released when the lights are in the on position.*

Current Limiter is a lighting control device that limits the input power of a track lighting fixture or incandescent medium screw base socket to a specific maximum level. The Current Limiter (1) must be an integral part of the fixture, (2) must be hard-wired into the track or the incandescent medium screw base socket fixture, (3) can only be replaced by manufacturer authorized technicians, and (4) must have the voltage ampere (VA) rating clearly marked on the track or fixture.

Lighting Zone *is a space or group of spaces within a building that has sufficiently similar requirements so that lighting can be automatically controlled in unison throughout the zone by an illumination controlling device or devices.* A lighting zone does not exceed one floor.

Lumen Maintenance Device *is a device capable of automatically adjusting the light output of a lighting system throughout a continuous range to provide a preset level of illumination.* Lumen maintenance control devices and systems use dimmers to automatically adjust the light output of the lighting system in order to deliver the design illuminance.

A new lighting system may deliver 30 percent more light than is actually needed, but as the lamps age, their light output will decline. The lumen maintenance device reduces the initial input of electrical energy to new lamps until the light output is at the designed illuminance level, thus saving energy.

Multi-Scene Dimming System *is a lighting control device that has the capability of setting light levels throughout a continuous range, and that has pre-established settings within the range.* This type of device is able to save energy by providing a convenient way to dim lights and reduce lighting power. Lighting control credits are available for such devices in hotels/motels, restaurants, auditoriums and theaters.

Occupant-sensing Device *is a device that automatically turns lights off soon after an area is vacated.* Occupant sensors detect whether a room or space is occupied, and automatically turns the lights off when occupants are not present. Various techniques are used to sense the presence of an occupant, including sensing infrared radiation (heat) emitted from the occupant, ultrasonic waves that sense changes in wave patterns when the room is occupied, and microwave radiation. These devices can be used to meet mandatory measure requirements; they can also be used to obtain lighting control credit for the building.

Tuning *is a lighting control device that allows authorized personnel only to select a single light level within a continuous range.* This type of device is able to save energy by providing a practical means of adjusting light output of a lighting system down to the specific level needed, rather than allowing excess illumination and consuming full power.

5.2 LIGHTING DESIGN PROCEDURES

This section discusses how the requirements of the Standards affect lighting system design. For procedures on documenting the lighting design, including compliance forms, see Section 5.3.

5.2.1 Mandatory Measures

The mandatory features and devices must be included in the building design whether compliance is shown by the prescriptive or the performance approach. These features have been proven cost-effective over a wide range of building occupancy types.

Many of the mandatory features and devices are requirements for manufacturers of building products, who must certify the performance of their products to the Energy Commission. It is the responsibility of the designer, however, to specify products that meet these requirements. Code enforcement officials, in turn, check that the mandatory features and specified devices are installed.

The mandatory requirements for lighting control devices (§119) specify minimum features for automatic time switch controls, occupancy sensors, automatic daylighting controls, lumen maintenance controls, and interior photocell sensors. Such devices must be certified to the Energy Commission by the manufacturer. Many of these requirements are part of standard practice in California and should be well understood by those responsible for designing or installing lighting systems.

A. Area Controls (§131(a))

The simplest way to improve lighting efficiency is to turn off the lights when they are not in use. All lighting systems must have switching or control capabilities to allow lights to be turned off when they are not needed.

Room Switching (§131(a)1) Independent lighting controls are required for each area enclosed by ceiling height partitions. In the simplest case, this means that each room must have its own switching; gang switching of several rooms is not allowed. The switch may be either a manual switch, an automatic control, or an occupancy sensor.

Accessibility (§131(a)1.A & B) All manually operated switching devices must be located so that personnel can see the controlled area when operating the switch(es). When not located within view of the lights or areas, the switch shall be annunciated to indicate the status of the lights (on or off).

Security or Emergency (§131(a) Exception No. 1) Lighting in areas within a building that must be continuously illuminated for reasons of building security or emergency egress are exempt from the switching requirements for a maximum of 0.5 watt per square foot. These lights must be designated as security or emergency egress areas on the plans, and the lights must be controlled by switches accessible only to authorized personnel. The remaining lighting in the area, however, is still subject to the area switching requirements.

Public Areas (§131(a) Exception No. 2) In public areas, such as building lobbies, concourses, etc., the switches may be located in areas accessible only to authorized personnel.

Other Devices (§131(a)2) If the room switching operates in conjunction with any other kind of lighting control device, there are two other requirements: 1) the other control device must allow the room switching to override its action, and 2) if the other control device is automatic, it must automatically reset to its normal operation mode without any further action.

For example, if there is an automatic control system that sweeps all the lights off in a group of offices at a certain hour, the room switch in any individual office must be able to override the sweep and turn the office's lights back on. The next time the automatic control sweeps the lights off, however, the override for that individual office must not remain in effect but must return to automatic mode and shut the lights off.

Example 5-3: Shut-off Control Override

Question A 5,000 square foot building will be equipped with an automatic control device to shut off the lights, in compliance with Section 131(b)--building shut-off. How are the local switches supposed to respond when an occupant wishes to turn on lights after the lights are shut off? **Answer**
The local switch (as specified in Section 131(a)) must allow the occupant to override the shut off and turn on the lights in their area (Section 131(a)2.A.), Following the override, the automatic function of the shut-off must resume, so that when the automatic control sweeps the lights off, these lights will be shut off unless the local switch again overrides the shut-off (Section 131(a)2.B.).

Example 5-4: Manual Switches and Automatic Controls

Question The card access system of a proposed building will automatically turn on the lobby and corridor lights when activated by someone entering the building after hours. In addition, the lobby and corridor lights are on an automatic time switch control. Are manual switches required for the lobby and corridor? **Answer**
Yes. The manual switch is still required under the area control mandatory measure requirement. Furthermore, the manual switch must be able to turn off the lights when either the automatic time switch control or card access system has turned them on. The automatic devices must be automatically reset.

B. Bi-Level Switching §131(b))

Most areas in buildings must be controlled so that the connected lighting load may be reduced by at least 50 percent in a reasonably uniform illumination pattern. The intent of this requirement is to achieve the reduction without losing use of any part of the space (see Figure 5-3). This bi-level switching may be achieved in a variety of ways, such as:

- Separately switching "on" every other luminaire in each row (checkerboard)
- Separately switching "on" alternate rows of luminaires
- Using dimming controls
- Separately switching lamps in each luminaire

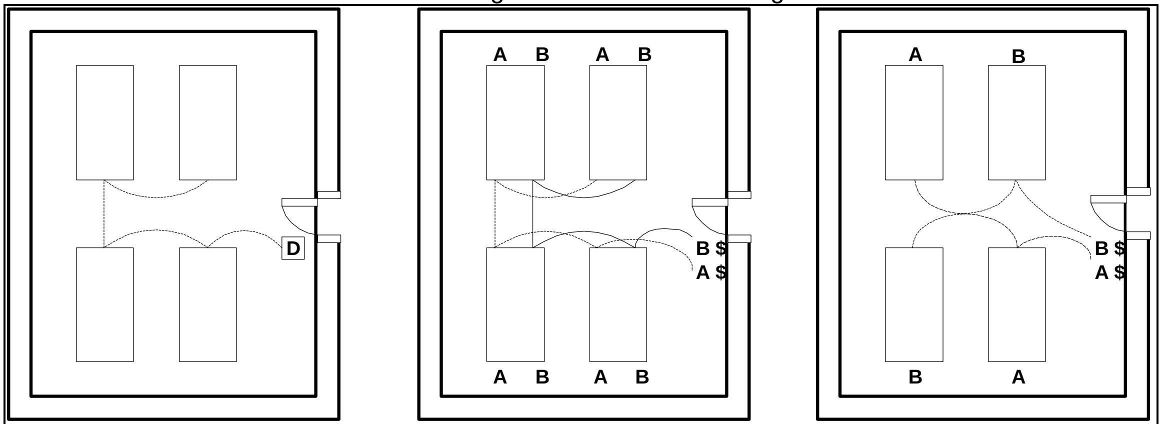
Bi-level switching is not required (Section 131(b) Exceptions 1, 2 and 3) when:

- The area has only one light source (luminaire),
- The area is less than 100 square feet,
- The lighting power density is less than 1.0 watts per square foot,
- The area is controlled by an occupant-sensing device,
- The area is a corridor, or
- An automatic time switch control device with a timed manual override switch independently controls each area that requires an individual switch.

C. Daylit Areas (§131(c))

The control of electric lighting in the area where daylighting enters a building through windows or skylights is addressed in the Standards. It falls under the mandatory requirement for separate switching in daylit areas, and may receive credit under the optional automatic controls

Figure 5-3: Bi-Level Switching



credits. Under the mandatory measures, where an enclosed space is greater than 250 square feet, the electric lighting within daylit area must be switched so that the lights can be controlled separately from the non-daylit areas (see definition of daylit area below). It is acceptable to achieve control in the daylit area by being able to shut off at least 50 percent of the lamps within the daylit area. This must be done by a control dedicated to serving only luminaires in the daylit area. If there are separate daylit areas for windows and skylights, they must be controlled separately.

The daylit area switching requirements are in addition to the bi-level switching requirements. Taken together, there are at least three ways to comply (see Figure 5-4). With the **4 Switch Option**, the bi-level switching is provided separately to the daylit area (within fifteen feet of the windows) and to the non-daylit area. The **3 Switch Option** also meets the requirements because switch "1" controls at least 50 percent of the lighting in the daylit area. Switch "2" controls the remainder of the lights in the daylit area and half of the lights in the non-daylit area. Switch "3" controls the remainder of lights in the non-daylit area. The **Dimmer Switch Option** controls the daylit and non-daylit areas separately, and the dimmer takes care of the bi-level illumination requirement. Daylight switching must be applied to a fixture if any portion of that fixture is within the daylit area.

The only exception to the requirement of providing the separate control to daylit areas is when there is not enough daylight to be used effectively. This is decided in one of two ways:

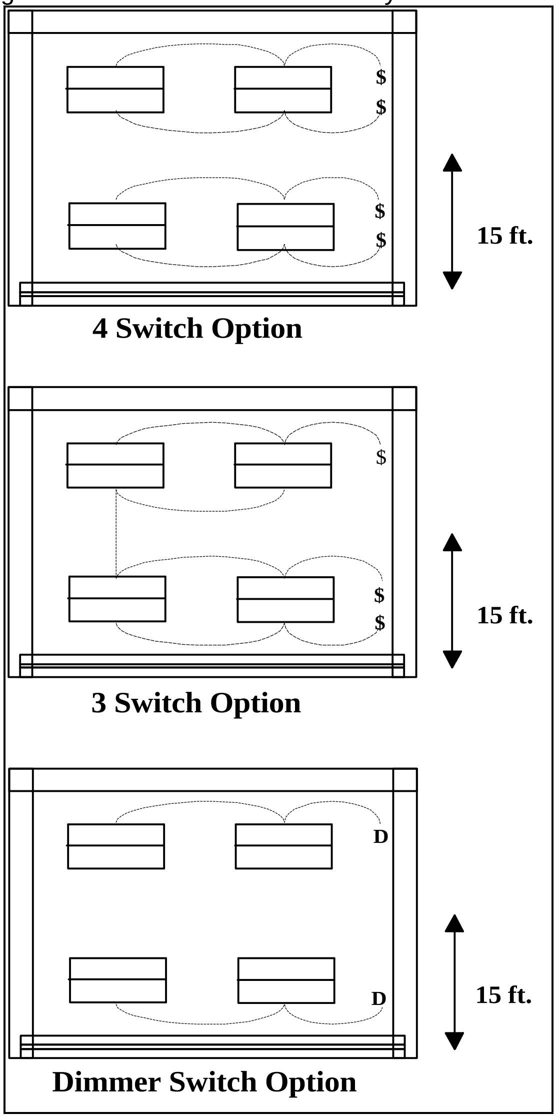
1. When the daylight to a window or skylight is so obstructed by adjacent structures, evergreen trees, or other natural objects that the effective use of daylighting is not reasonable. This determination must be made by the local enforcement agency.

2. When the effective aperture of the window is less than 0.1 (or of the skylight is less than 0.01). A low effective aperture prevents usable daylight from entering the area; it is caused by small glazing area, low transmission glazing materials, or a combination of both. (See definition of **Effective Aperture** below.)

Daylit Area is the space on the floor that is the larger of (a) plus (b), or (c);

(a) For areas daylit by vertical glazing, the daylit area has a length of 15 feet, or the distance on the floor, perpendicular to the glazing, to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side, the distance to an opaque partition, or one half the distance to the closest skylight or vertical glazing, whichever is least *(see Figure 5-5)*.

Figure 5-4: Combined Bi-level and Daylit Area Switching



(b) For areas daylit by horizontal glazing, the daylit area is the footprint of the skylight plus, in each of the lateral and longitudinal dimensions of the skylight, the lesser of the floor-to-ceiling height, the distance to the nearest 60-inch or higher opaque partition, or one-half the horizontal distance to the edge of the closest skylight or vertical glazing *(see Figure 5-6)*.

(c) The daylit area calculated using a method approved by the Energy Commission. Such methods include DOE 2.1D and E, Superlite, Quicklite and other computer-based models that determine the daylit area based on modeling the features of the space.

Effective Aperture (EA) for windows equates to the visible light transmittance (VLT) times the window wall ratio. The EA for windows is calculated for each room with daylighting (see Table 5-1). The window wall ratio used in calculating EA is determined from the Exterior Wall Area of the room with the window(s) (measured from floor to ceiling), and from the windows area. Windows with an EA greater than or equal to 0.1 indicate sufficient daylight is available to require a separate control for the daylit area.

For the EA calculation of a skylight see Table 5-1.

NOTE:

The skylight-to-roof area ratio is determined from the skylight area and the gross exterior roof area of each daylit space. 0.85 is a dirt depreciation factor for the skylight.

See following pages for discussion of Well Index and (Visible Light Transmittance). See Section 3.1.2A for **Surface Definition** terms.

Table 5-1: Effective Aperture Matrix

Is Adequate Daylighting Available?

	WINDOWS (Vertical Glazing			
	Window/Wall Ratio			
Glazing Type	**< 0.10**	**0.10 to 0.20**	**0.20 to 0.40**	**> 0.40**
VLT > 0.60	NO	CALC*	YES	YES
VLT 0.35 to 0.59	NO	CALC*	CALC*	YES
VLT < 0.35	NO	NO	CALC*	CALC*
*Window EA = VLT x Window Wall Ratio				

	SKYLIGHTS (Horizontal Glazing)		
	Skylight-to-Roof Area Ratio		
Glazing Type	**< 0.01**	**0.01 to 0.03**	**> 0.03**
VLT > 0.630	NO	CALC**	YES
VLT 0.35 to 0.59	NO	CALC**	YES
VLT < 0.35	NO	CALC**	CALC**

**Skylight EA =

$$\frac{\text{WI x VLT x Skylight-to-Roof Area Ratio x 0.85}}{\text{Gross Exterior Roof Area}}$$

NOTE: This skylight matrix does not account for well index (WI). If the skylight has a light well, the EA could be substantially lower. It is recommended that the EA be calculated in such cases.

Example 5-5: Effective Aperture Matrix

Question
A room has a window area of 90 sf. The exterior wall has a gross area of 180 sf. The window glazing has a visible light transmittance (VLT) of 0.31. Do the daylit area switching requirements apply in this room? **Answer**
Yes. The window wall ratio (WWR) for the room is 90 sf / 180 sf = 0.50. The effective aperture, EA = 0.50 x 0.31 = 0.155, which is greater than 0.1 (exception for inadequate daylight does not apply). (With a WWR of 0.50 and a VLT of less than 0.35, the matrix in Table 5-1 also indicates that the EA is high enough that adequate daylighting is available). Daylighting control credits are available for the room (Table 5-10).

Table 5-1, above, can be used as a simplified method for calculating the EA. It indicates when the EA is low enough to invoke the exception to the requirements for daylight switching control. Each vertical column of the table corresponds to a window wall ratio or skylight-to-roof ratio range. Each horizontal row of the matrix corresponds to a range of VLTs. In questionable cases, indicated by "DO CALC" on Table 5-1, the EA should be calculated to obtain a precise answer as to whether the daylit area must be separately controlled.

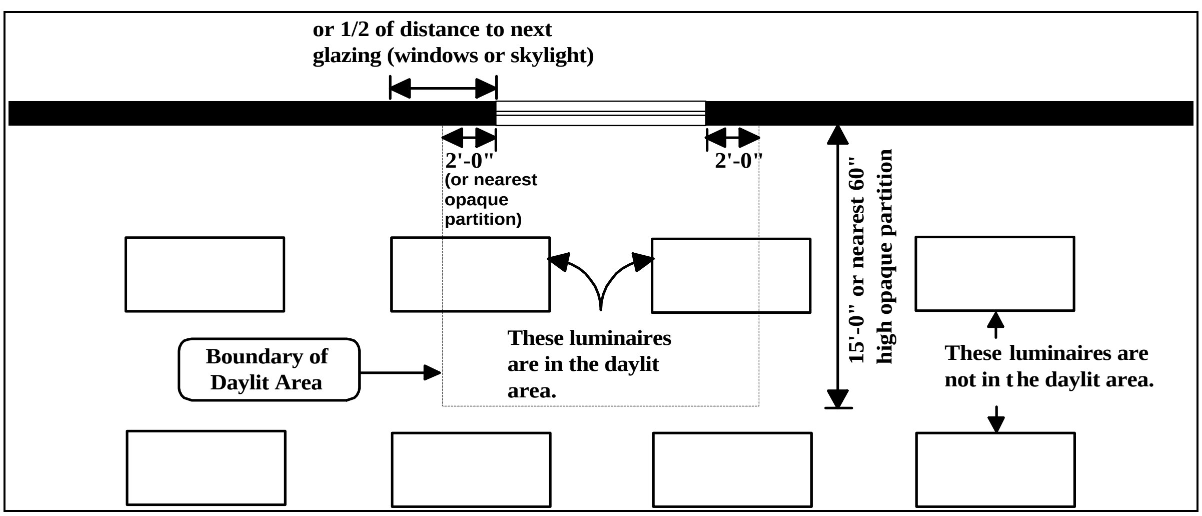
If, instead of using Table 5-1, the EA is to be calculated, the following terms must also be understood.

Visible Light Transmittance (VLT) is a property of the glass or plastic glazing material. The value of VLT for a given material is found in the manufacturer's literature.

Example 5-6: Skylight/Daylit Area

Question
What is the daylit area associated with the skylight shown in Figure 5-6**?** **Answer**
The daylit area of the skylight is calculated from the length and width of the skylight footprint, and from the ceiling height (there are no opaque partitions or nearby windows/skylights). The length of the daylit area is the length of the skylight (10') plus the floor-to-ceiling height on each end (11' + 11'), for a total daylit area length of 32'. The width of the daylit area is the width of the skylight (5') plus the floor-to-ceiling height on each end (11' + 11') for a total daylit area length of 27'. The daylit area is its length times its width, or 32' x 27' = 864 sf.

Figure 5-5: Window Daylit Area



Well Index *(Efficiency of Well) is the ratio of the amount of visible light leaving a skylight well to the amount of visible light entering the skylight well . The Well Index is calculated as follows:*

(a) For rectangular wells:

Well index =

$$\frac{Well \quad Height \times (well \quad length + well \quad width)}{2 \times well \quad length \times well \quad width}$$

or

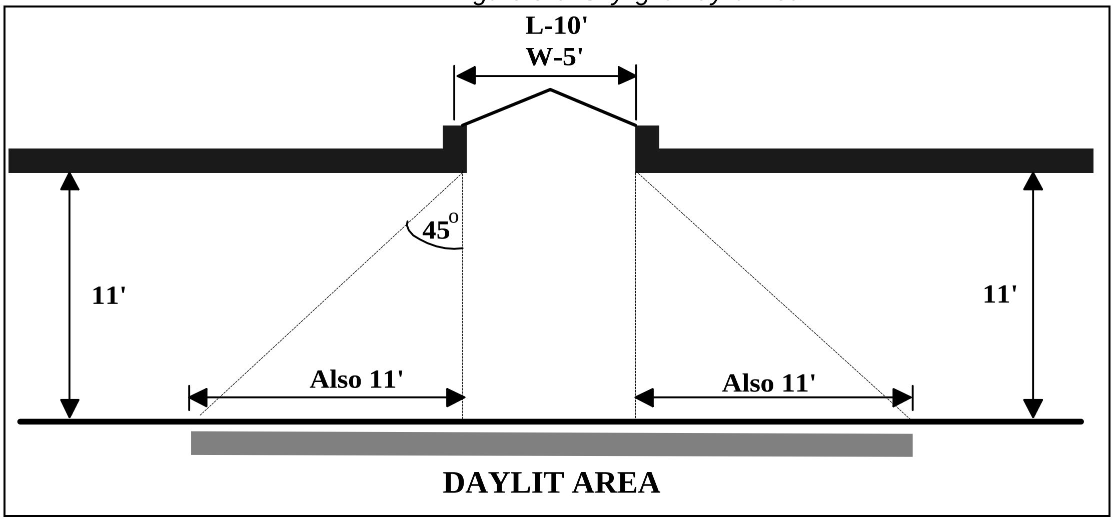
(b) for irregular shaped wells:

Well index =

$$\frac{\mathbf{Well \quad height \times well \quad perimeter}}{\mathbf{4 \times well \quad area}}$$

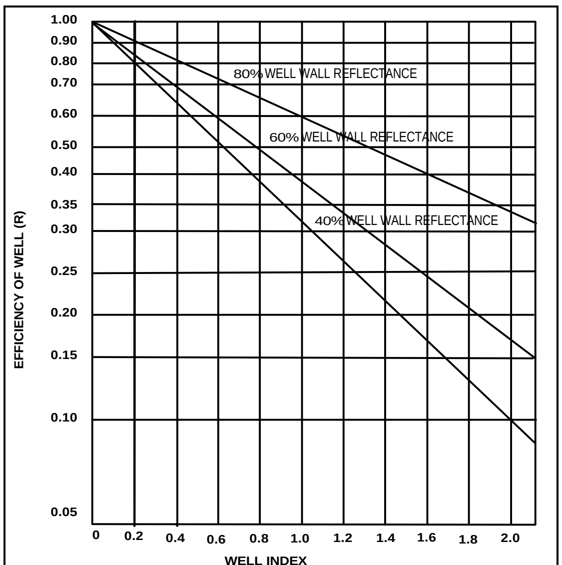
where the length, width, perimeter and area are measured at the bottom of the well.

Figure 5-6: Skylight Daylit Area



The area weighted average reflectance [of the walls of the well (R)] is the average calculated by the area of reflectance of all surfaces associated with a skylight. Reflectance is based on the surface color and type. To acquire information on the values for various surface types refer to the 1987 Illumination Engineering Society Handbook, or use the Munsell reflectance rating system. See Figure 5-7 to determine the well index.

Figure 5-7: Well Index (Efficiency of Well) Graph



Source: Fig 7-38, *IES Lighting Handbook,* 1984 Reference Volume

Example 5-7: Skylight Effective Aperture

Question

A skylight well has bottom dimensions of 6 ft by 8 ft. The well height is 4 ft. The inside surface of the well is painted with a blue paint having a reflectance of 50%. The skylight area is 16 sf. It has a visible light transmittance of 35%. The gross exterior roof area of the room is 200 sf. What is the effective aperture?

Answer

First, calculate the well index:

$$\text{Well index} = \frac{\text{Well hgt x (well length + well width)}}{\text{2 x well length x well width}}$$

$$\left(\frac{4\text{ ft x }(8\text{ ft}+6\text{ ft})}{2\text{ x }8\text{ ft x }6\text{ ft}}\right)=0.58$$

Next, find the well index (efficiency of well) from Figure 5-7. Enter at the bottom at 0.58. Draw a vertical line up to the 50% reflectance line (interpolate midway between the 40% and 60% Reflectance lines). From the intersection, draw a horizontal line left to find the well index of 0.56.

Then calculate the skylight-to-roof ratio of the room: 16 sf / 200 sf = 0.08.

Finally, calculate the EA by multiplying together the well index, VLT, skylight-to-roof area ratio, and dirt depreciation (0.85) and divide by the gross exterior roof area (200sf).

Skylight EA = 0.58 x 0.35 x 0.08 x 0.85/200 = .000. No daylit area controls required.

D. Shut-Off Controls (§131(d))

The Standards require that most buildings, or separately metered space greater than 5,000 square feet of conditioned space, have an automatic control to shut off the lights. Additionally, if the building has more than one floor, each floor shall have the lights on the floor controlled by a separate automatic control device (or control point if a multiple point control system).

The areas exempted from automatic shut-off are:

- Buildings or separately metered spaces less than 5,000 square feet
- Areas that must be continuously lit imply 24 hour operation, such as hotel lobbies and 24-hour, 365 day/year grocery stores where lights are never turned off.
- Areas lit in a manner requiring manual operation of the lighting system *such as* spaces which always have varying and unpredictable operating schedules, or spaces with lighting systems equipped with high intensity discharge (HID) lamps AND where the use of the space results in unpredictable on/off operation. The

space requires manual operation because of the longer start/restart time of HID lamps coupled with the unpredictable schedule.

> **NOTE:**
> Most facilities equipped with HID lighting will not fall under this exception because an operating schedule will be reasonable to predict. A facility with a predictable operating schedule and metal halide lighting could still use automatic shut-off without posing a risk to people working or conducting business in the building.

- Security or emergency egress lighting that must be continuously lit, provided it does not exceed 1/2 watt per square foot and the area is controlled by switches accessible only to authorized personnel (the security or egress area must be documented on the plans)
- Corridors, guest rooms, and lodging quarters of high-rise residential buildings or hotel/motels

The shut-off control need not be a single control, but may include automatic time switches, occupancy sensors, or other automatic controls (see Figures 5-8 and 5-9.)

When an occupant-sensing device is used to meet the automatic shut-off requirement, it is required to be installed in accordance with manufacturer's instructions with regard to placement of the sensors.

Automatic time switches with programmable solid state perpetual calendar control devices can also be used to meet the shut-off requirement. These devices are typically available with multiple channels of control, and may also be used to meet the mechanical system automatic time switch control requirements.

Figure 5-8: Timed Manual Override

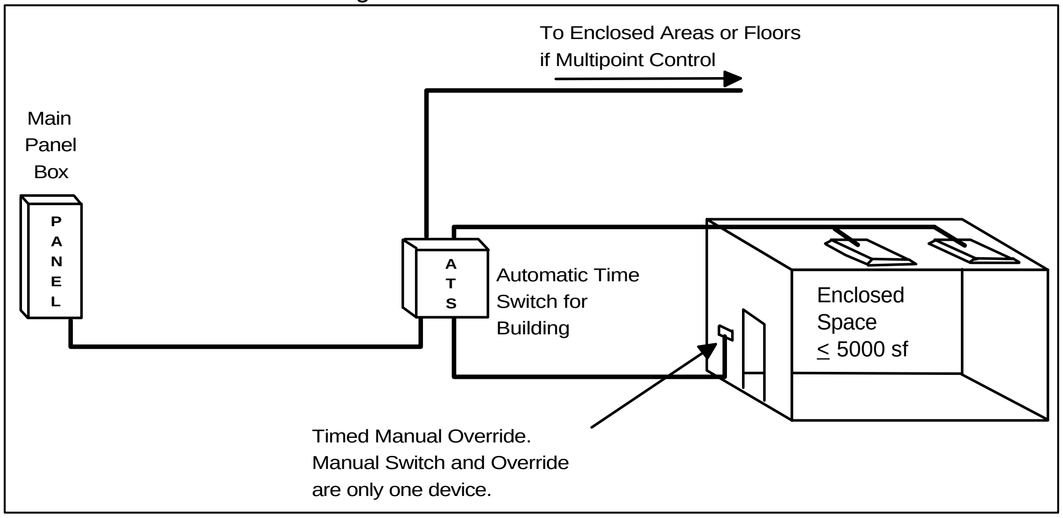
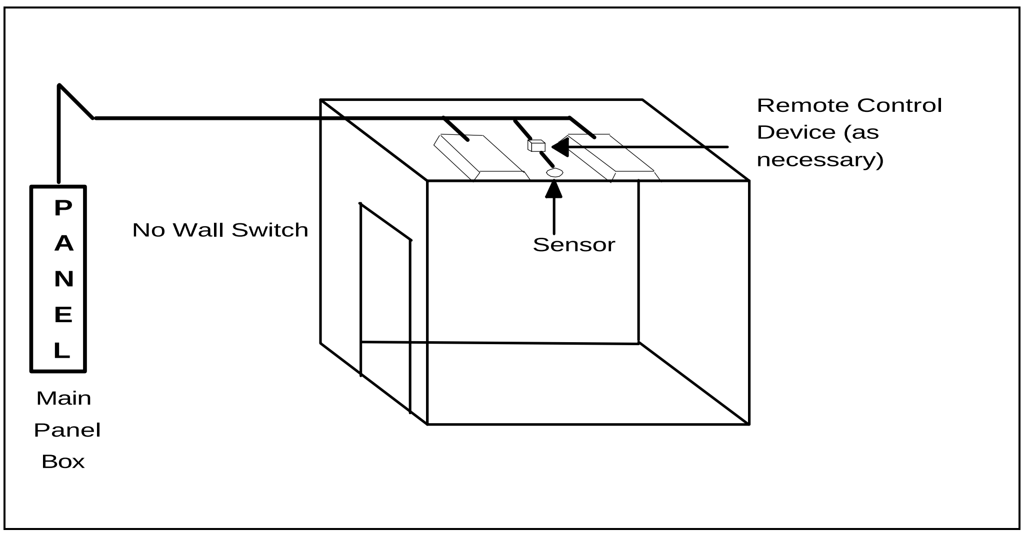


Figure 5-9: Occupant-sensing Device Shut-off



If an automatic time switch control device is used for shut-off control, it must be certified, incorporate an automatic holiday shut-off that turns off all lighting loads for at least 24 hours and then resume normal scheduled operation. Holiday scheduling is not required for: retail stores and associated malls, restaurants, grocery stores, churches, and theaters. If an automatic time switch control device is used for shut off, the control is required to be designed with override switching devices. The override switching devices shall:

- Control an area not exceeding 5,000 square feet on a single floor. For malls and arcades, auditoriums, single tenant retail spaces, industrial facilities, and arenas, the area controlled may not exceed 20,000 square feet.
- Be readily accessible
- Be manually operated

- Allow the operator to see the lights or area controlled or be annunciated (see definition in Section 5.1.2C)

- Provide an override for not more than 2 hours. In malls and arcades, auditoriums, single tenant retail spaces, industrial facilities, and arenas where captive-key override (see definition in Section 5.1.2C) is utilized, a 2 hour override limit is not required.

E. Display Lighting (§131(e))

Display lighting shall be separately switched on circuits that are 20 amps or less. The general lighting should be on separate switching so it will be operated without having to turn on the display lighting (as, for example, when the cleaning crew is working at night and there is no need for the displays to be lit).

F. Exterior Lights (§131(f))

The Standards also require automatic control of all exterior lighting that is served from a lighting panel **within** the building. The exterior lights shall be controlled by a directional photocell or an astronomical time switch that automatically turns off the exterior lighting when daylight is available. A building automation system with a program that is capable of duplicating the action of an astronomical time switch is acceptable.

When determining the type of control to use, night time ambient lighting such as street lights, sports stadiums, car headlights, etc. should be considered because they may effect the performance of a directional photocell.

Lights in parking garages, tunnels, and large covered areas that are required to be on during the day are exempt from this requirement.

G. Tandem Wiring (§132)

Pairs of one-lamp or three-lamp recessed fluorescent luminaires that are 1) on the same switch control, 2) in the same enclosed area and 3) within 10 feet of each other in an accessible ceiling space, must be tandem wired (see Figure 5-10). Single lamp ballasts should not be used.

Tandem wiring refers to the arrangement where a ballast operates a lamp in one luminaire and a lamp in an adjacent luminaire. Surface or pendant mounted fixtures that are continuous with each other must also be tandem.

Luminaires that are exempt from this requirement are:

- Surface or pendant mounted luminaires that are not continuous

- Florescent luminaires that use electronic high frequency ballasts

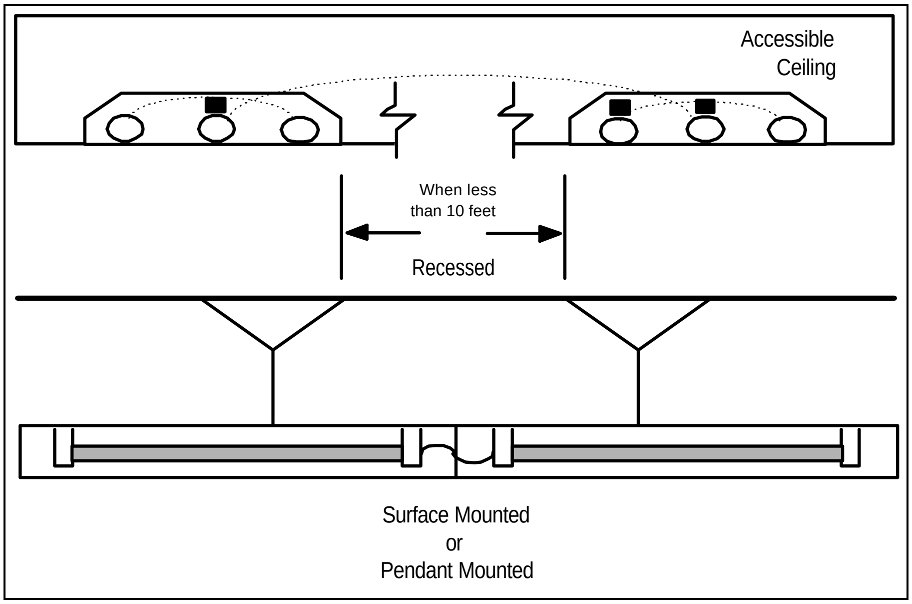
Single lamp ballasts may be used in emergency battery-ballast units and when there are an odd number of lamps or where there are multiple groups of bi-level switching and the control scheme produces two one-lamp ballasts adjacent to each other, but controlled by different switches.

Exit signs are exempt.

H. Certified Automatic Lighting Control Devices (§119)

All automatic lighting control devices must be certified by the manufacturer to the Energy Commission before they can be installed in a building. The certification of the performance of these devices to the Energy Commission is the responsibility of the manufacturer. Once a device is certified, it will be listed in the Directory of Automatic Lighting Control Devices. Call the Energy Hotline at 1-800-772-3300 to obtain more information. All devices must have instructions for installation and start-up calibration, must be installed in accordance with such directions, and must have a status signal (visual or audio) that warns of failure or malfunction. In addition, certain devices must meet the specialized requirements listed below.

Figure 5-10: Tandem Wiring



Automatic Time Switches (ATS) (§119(c))

Automatic time switches are used to automatically shut-off the lights according to pre-established schedules appropriate to the building occupants. The device is required to have separate program schedules for weekdays and weekends. To prevent losing the time of day and the programmed schedules, the time switch must contain back-up power for at least 10 hours during power interruption.

NOTE:

Most building automation systems can meet these requirements, provided they are certified to the Energy Commission.

Occupant-Sensors (§119(d))

Occupant-sensing devices shall be capable of automatically turning off all of the lights in an area no more than 30 minutes after the area has been vacated.

Additionally, the following sensors must meet special requirements.

- The ultrasonic type must meet certain minimum health requirements, and have the built-in ability for sensitivity calibration (to reduce false signals for both on and off).
- The microwave devices must have emission controls, permanently affixed installation requirements, and built-in sensitivity adjustment.

Automatic Daylighting Controls (§119(e))

Daylighting controls consist of photocell sensors that compare actual illumination levels with a reference illumination level and reduce the electric lighting until the reference level has been reached.

When automatic daylighting control devices and systems are used, they must be certified to the Energy Commission that they meet the following requirements:

- The ability to reduce the general lighting power of the controlled area by at least 50 percent uniformly (either by separate control of multiple lamps or by dimming)
- When a dimmer is used it must provide reduced flicker operation (see definitions) over the dimming range without causing premature lamp failure
- For stepped dimming, provide a minimum of 3 minutes time delay between steps to prevent cycling
- Single- or multiple-stepped switching controls with distinct on and off settings for each step shall include sufficient separation (dead-band) between points to prevent cycling
- All of the above automatic daylighting devices shall have a visual or audible signal to indicate device failure or malfunction. They shall be provided with manufacturers step-by-step installation and calibration instruction.

Lumen Maintenance Control (§119(f))

Lumen maintenance control devices and systems must meet similar requirements for Energy Commission certification as dimmed daylighting. These include reduced flicker operation, prevention of premature lamp failure, and step-by-step installation and start-up calibration instructions. Additionally, they shall be capable of reducing the general lighting in the controlled area by at least 30 percent uniformly by dimming. The system must include an alarm (either audible or visual) to indicate when a specified setpoint has been reached.

Interior Photocell (§119(g))

Both daylighting and lumen maintenance control systems incorporate a photocell that measures the amount of light at a reference location. The photocell provides light level information to the controller so it can decide when to increase or decrease the light level.

Photocell devices must be certified to the Energy Commission as not having mechanical slide covers or other means which allow easy unauthorized adjusting or disabling of the photocell. In addition, they shall not be combined in a wall mounted occupant-sensing device. (This means that wall-mounted occupant-sensing devices with photocell controls can be certified as occupant-sensing devices but not interior photocell devices.)

I. Certified Ballasts and Luminaires

Fluorescent lamp ballasts and luminaires with fluorescent lamp ballasts are regulated by the Appliance Efficiency Regulations . Those certified to the Energy Commission are listed in the Directory of Certified Luminaires and Ballasts. Call the Energy Hotline at 1-800-772-3300 to obtain more information. All standard wattage four-foot and eight-foot lamp and ballast combinations commonly installed in nonresidential buildings are included in this directory.

Detailed information on the energy efficiency standards for fluorescent lamp ballasts is available in a separate Energy Commission publication. This publication is called the Advanced Lighting Guidelines and was developed in conjunction with the Lighting Efficiency Advisory Group (LEAGue). It contains information on a variety of luminaires, lamps and ballasts that can be used to demonstrate compliance with the Standards. Appendix F has information on how to obtain these documents.

J. High Rise Residential Living Quarters and Hotel/Motel Guest Rooms (§130(b))

The Standards require that lighting in high-rise residential living quarters and in hotel/motel guest rooms comply with lighting requirements similar to the lighting requirements of the Residential Standards.

Kitchen Lighting

The Standards require that general lighting in high rise residential or hotel/motel kitchens have an efficacy of at least 40 lumens per watt and be controlled by the most accessible switch(es) in the kitchen. The light switch location determines how the occupant will use the lighting. If more than one set of light fixtures provide general lighting, those controlled by the most accessible switch are considered general lighting. Luminaries used only for specific decorative effects (and which are not the only luminaries in the kitchen) need not meet this requirement.

General lighting is lighting designed to provide a substantially uniform level of light distribution throughout a space. This can be achieved by light fixtures in the ceiling or around the perimeter of the room. Lighting fixtures under cabinets may meet the general lighting requirements if they provide uniform light distribution in the kitchen (see Figure 5-11). A luminaire which is the only lighting in a kitchen will be considered general lighting.

Bathroom Lighting

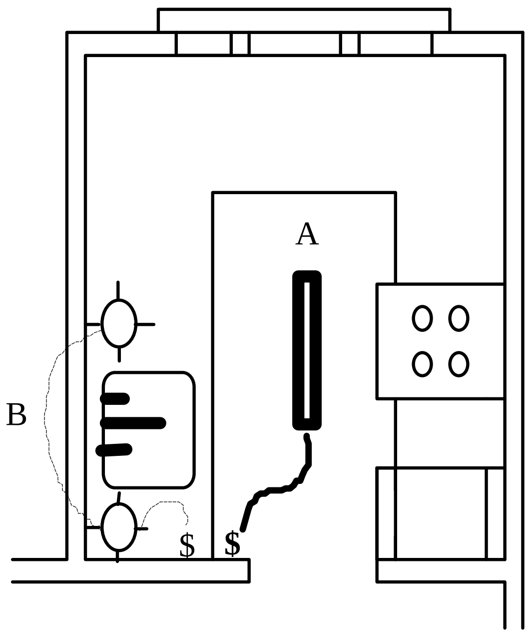
The Standards require that each room containing a water closet must have at least one luminaire with lamps with an efficacy of at least 40 lumens per watt. As an alternative, this requirement may be met by installing the high efficacy luminaire in an adjacent room that has complementary plumbing fixtures (See Figure 5-12).

If there is more than one luminaire in the room, the high-efficacy luminaire must be switched at an entrance to the room.

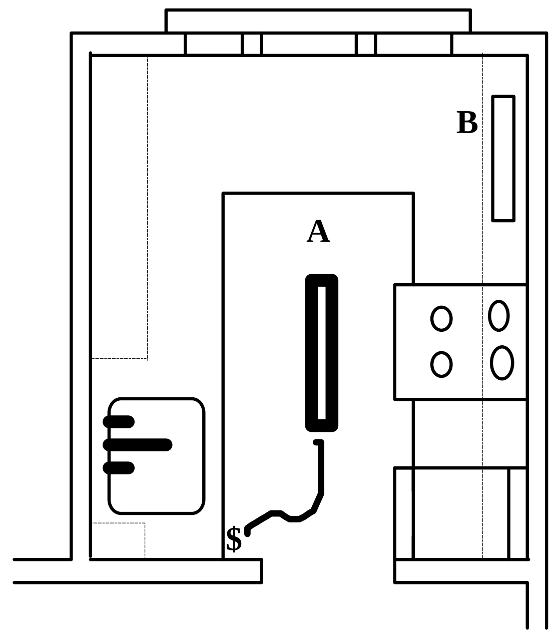
Table 5-2: Typical Efficacy of Luminaires

Light Source	Type	Rated Lamp Watts	Typical Efficacy Lumens/Watt[1]
Incandescent	Standard	40 - 100	14 - 18
Incandescent	Halogen	40 - 250	20[2]
Incandescent	Halogen IR	See footnote[3]	Up to 30
Fluorescent (Lamp/Ballast Systems)[4]	Full-Size, 4' Long	32 - 40	69 - 91
	U-Shaped T-8 Bipin	16 - 31	78 - 90
	Compact Fluorescent	5 - 9	26 - 38
	Compact Fluorescent	13 +	42 - 58
Metal Halide	Metal Halide	32 - 175	50 - 90
High Pressure Sodium	White High Pressure Sodium	35 - 100	36 - 55

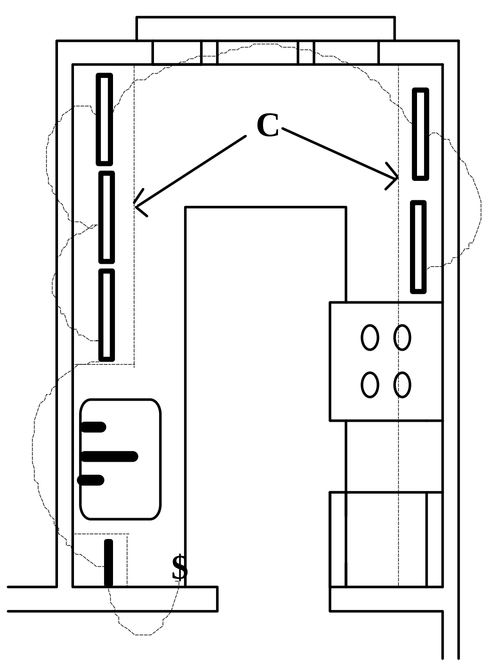
1 Includes power consumed by ballasts where applicable.
2 Halogen capsule incandescent lamps may be the most efficient light source for highlighting applications. Most halogen lamps are designed to produce a beam of directed light. Manufacturer's data typically list the "candlepower" intensity of that beam, rather than lumens (lumens measure total light output in all directions).
3 A new technology using infrared reflecting films on the halogen capsules has increased output up to 30 lumens/watt for some high wattage lamps.
4 Efficacy of fluorescent lighting varies depending on lamp and ballast types.



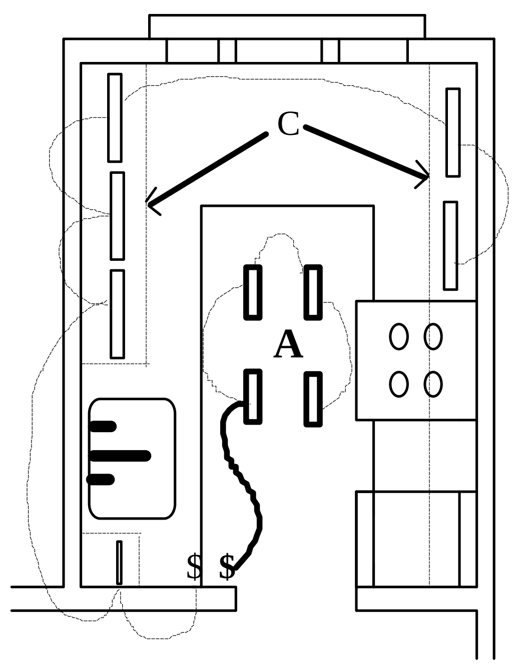
"A" must be fluorescent



"A" must be fluorescent
“B” alone is not general lighting.

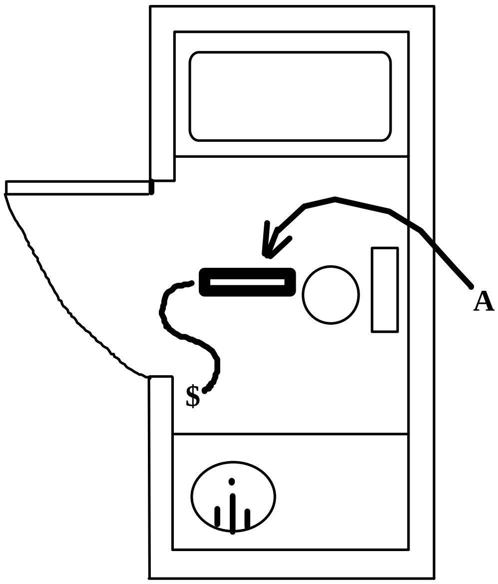


All of "C" must be fluorescent

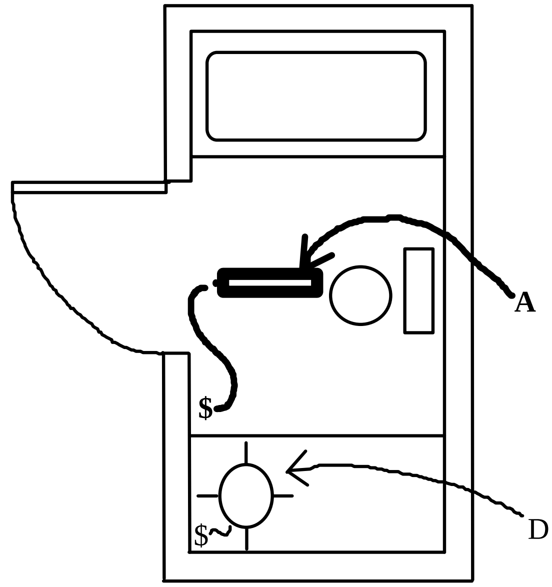


All of "A" or "C" must be fluorescent.
If "C" then "C" must be the most accessible switch.

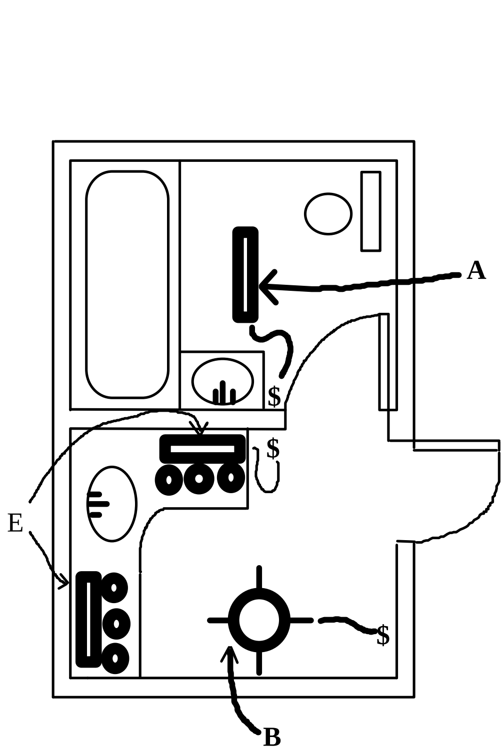
Figure 5-11: Residential and Hotel/Motel Guestroom Kitchen Lighting Examples



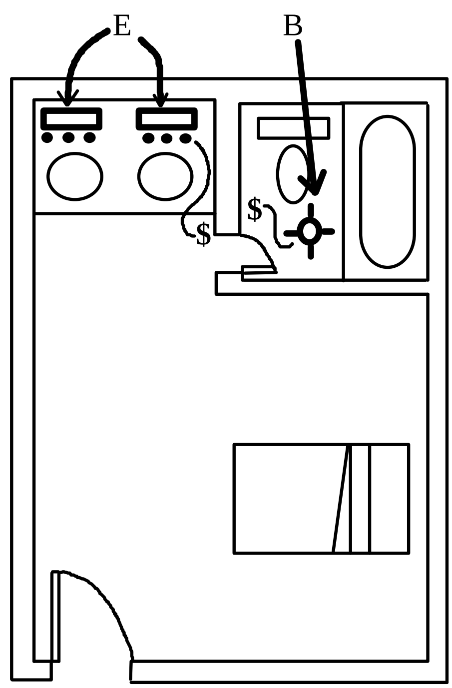
"A" must be fluorescent



"A" must be fluorescent;
"D" can be incandescent



"A", "B" or "E" must be fluorescent



"B" or "E" must be fluorescent

Figure 5-12: Residential and Hotel/Motel Guestroom
Bathroom Lighting Examples

General

Luminaries installed to meet the 40 lumens per watt requirements cannot contain medium base incandescent lamp sockets, and must be on separate switches from incandescent lighting.

All incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (I.C.) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials (ICBO).

Recessed lighting fixtures left uninsulated significantly increase the heat loss and heat gain through the roof/ceiling area.

The designer has the option to exempt as many as 10 percent (by number) of the guest rooms in a hotel/motel from this requirement. This may be desirable for special consideration rooms, such as executive suites, penthouses, etc.

5.2.2 Prescriptive Approach

The prescriptive approach for lighting involves a comparison of the building's Allowed Lighting Power with its Actual Lighting Power (as adjusted). This section describes the procedures and methods for using the prescriptive approach to comply with the Standards. It incorporates common energy efficiency measures that are easily integrated into building designs.

To determine the Allowed Lighting Power using the prescriptive approach, there are three methods: the Complete Building, the Area Category and the Tailored Method.

NOTE:

The Complete Building Method can be used for tenant improvements where at least 90 percent of the permitted space is one Type of Use (which may include the following areas if they serve as support for the primary Type of Use: lobbies, corridors, restrooms and storage).

A. Allowed Lighting Power - Complete Building Method (§146(b)1)

The Complete Building Method (see Figure 5-13) of determining the Allowed Lighting Power can only be applied when all areas in the entire building are complete. The building must consist of one Type of Use for a minimum of 90 percent of the conditioned floor area (in determining the area of the primary Type of Use, include the following areas if they serve as support for the primary Type of Use: lobbies, corridors, restrooms and storage). There cannot be any unfinished areas and complete lighting plans must be submitted if any lighting wattage is being transferred from one area of the building to another. To determine the Allowed Lighting Power, multiply the complete building conditioned floor area times the lighting power density for the specific building type, as found in Table 5-3.

NOTE:

High-rise residential and hotel/motel buildings cannot use the Complete Building Method.

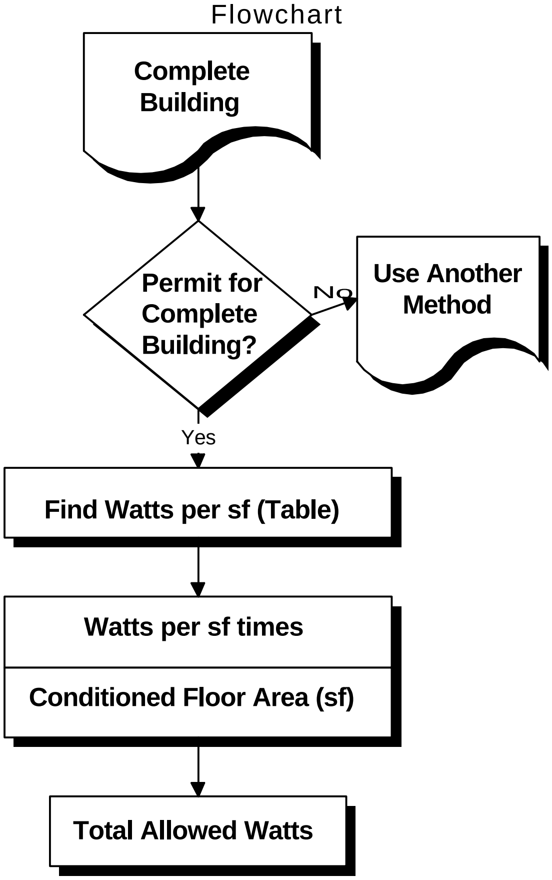
Table 5-3: Complete Building Method Lighting Power Density Values

Type of Use	Watts/sf.
General Commercial and Industrial Work Buildings	High 1.2 Low 1.0
Grocery Store	1.5
Industrial and Commercial Storage Buildings	0.7
Medical Buildings and Clinics	1.2
Office Building	1.2
Religious Facilities, Auditorium, and Convention Centers	1.8
Restaurants	1.2
Retail and Wholesale Store	1.7
Schools	1.4
Theaters	1.3
All Others	0.6

Example 5-8: Complete Building Method

Question
A 10,000 sf Medical Clinic Building is to be built. What is its Allowed Lighting Power under the Complete Building Approach?
Answer
From Table 5-3, Medical Buildings and Clinics are allowed 1.2 watts per square foot. The Allowed Lighting Power is 10,000 x 1.2 = 12,000 watts.

Figure 5-13: Complete Building Method Flowchart



Exception to Section 146(b)2: The tailored method (Section 146(b)3) may be used for up to 10 percent of the floor area of a building that is otherwise using the area category method. The two lighting methods cannot be used for the same floor area. The floor area for calculations based on the tailored method must be subtracted from the floor area for the remainder of the building lighting calculations. Trade offs of lighting between the two methods is not allowed.

B. Allowed Lighting Power - Area Category Method (§146(b)2)

The Area Category Method is more flexible than the Complete Building Method because it can be used for multiple tenants, or partially completed, buildings. Areas not covered by the current permit are ignored. When the lighting in these areas is completed later under a new permit the applicant may show compliance with any of the lighting options except the Complete Building Method.

The Area Category Method shown in flowchart form in Figure 5-14 divides a building into primary function areas. Each function area is defined under Occupancy Type in Standards Section 101(see Section 5.1.2c.) . When using this method, each function area in the building must be included as a separate area. Boundaries between primary function areas may or may not consist of walls or partitions. For example, it is not necessary to separate aisles or entries within primary function areas. Other circumstances where a boundary between primary function areas is not defined by partitions, i.e. the kitchen and dining areas within a fast food restaurant.

Figure 5-15 shows a function area that has interior, nonbounding partitions (dotted) and bounding partitions (solid). The area is calculated by multiplying the width times the depth, as measured from the center of the bounding partitions.

The Allowed Lighting Power is determined by multiplying the area of each function times the lighting power density for that function. The Total Allowed Watts is the summation of the

Figure 5-14: Area Category Method Flowchart

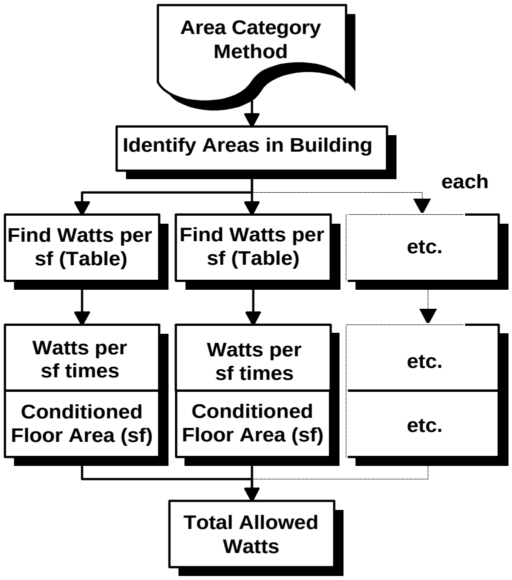
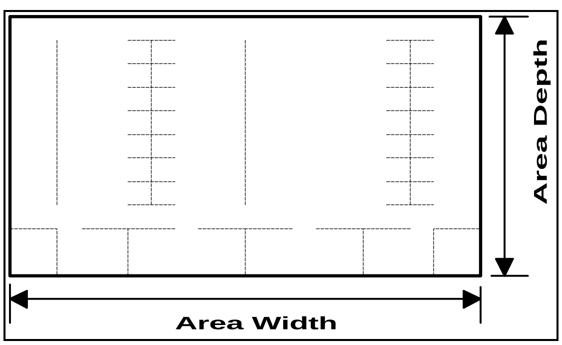


Figure 5-15: Calculating Lighting Area



Allowed Lighting Power for each area covered by the permit application. If lighting wattage is to be transferred from one area to another, this is acceptable only for areas for which lighting plans are submitted and lighting is being installed as part of the same approved permit. The Primary Function area allotments are found in Table 5-4.

Table 5-4: Area Category Method LPD Values

Primary Function	Allowed Lighting Power
All Other	0.6
Auditorium	2.0[1]
Auto Repair	1.2
Bank	1.4
Classrooms/Training	1.6
Commercial Storage	0.6
Conference Centers	1.6[1]
Convention Centers	1.6[1]
Corridors	0.6
Dining	1.1[1]
Dressing Room (Gymnasium)	0.9
Electrical Rooms	0.7
Exercise Center	1.0
Exhibit, Museum	2.0
Financial Institution	1.4
Food Preparation	1.7
General Commercial Work	
High Bay	1.2
Low Bay	1.0
General Industrial Work	
High Bay	1.2
Low Bay	1.0
Grocery Store	1.6
Gymnasium	1.0
Hotel Function Area	2.2[1]
Industrial Storage	0.6
Kitchen	1.7
Laundry 0.9	
Lecture	1.6[1]
Library	
Reading Areas	1.2
Stacks	1.5
Lobbies:	
Hotel Lobby	2.2[1]
Main Entry Lobby	1.5[1]
Reception/Waiting	1.1[1]
Locker Room	0.9
Lounge/Recreation	1.1

LTG

Primary Function	Allowed Lighting Power
Malls, Arcades, and Atria	1.2[1]
Mechanical Rooms	0.7
Medical and Clinical Care	1.4
Meeting Centers	1.6[1]
Multipurpose Centers	1.6[1]
Museum Exhibit	2.0
Office	1.3
Precision Commercial Work	1.5
Precision Industrial Work	1.5
Religious Worship	2.1[1]
Restrooms	0.6
Retail Sales	2.0
Stairs	0.6
Support Areas	0.6
Theaters	
Motion Picture	0.9
Performance	1.4[1]
Vocational Room	1.6
Wholesale Showrooms	2.0

1. The smallest of the following values may be added to the allowed lighting power listed in Table No. 1-N, for ornamental chandeliers and sconces that are switched or dimmed on circuits different from the circuits for general lighting:

a. 20 watts per cubic foot times the volume of the chandelier or sconce; or
b. 1 watt per square foot times the area of the task space that the chandelier or sconce is in; or
c. the actual design wattage of the chandelier or sconce.

Chandeliers and Sconces §146(b)3H

Certain function areas use decorative lighting in the form of ornamental chandeliers or sconces. Areas shown in Table 5-4, with a reference to Footnote 1, qualify for an additional lighting allotment that may be added to the Allowed Lighting Power under the Area Category Method. Ornamental chandeliers are ceiling-mounted or suspended decorative luminaires that use glass crystal, ornamental metal or other decorative materials. Sconces are wall mounted decorative lighting fixtures.

Supplemental watts can be added to the Allowed Lighting Power to accommodate the decorative portion of the fixture.

Example 5-9: Area Category Method

Question

A 10,000 square foot multi-use building is to be built consisting of :

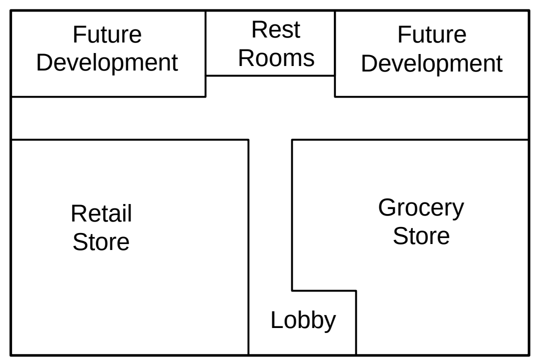
A) 500 square foot main entry lobby

B) 2,000 square foot corridors and restroom

C) 3,000 square foot grocery store

D) 2,500 square foot retail, and

E) 2,000 square foot future development



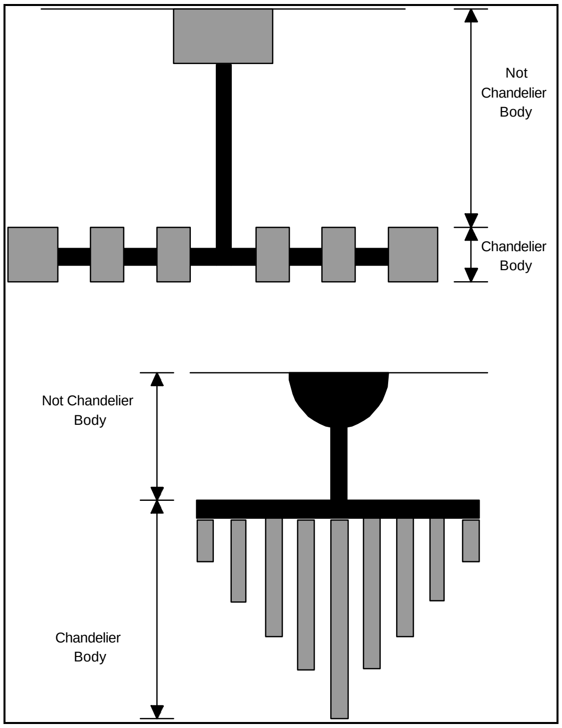
What is the Allowed Lighting Power under the Area Category Method?

Answer

A) Main Entry	1.5 w/sf	500sf	750W
B) Corridors and Restrooms	0.6 w/sf	2,000sf	1,200W
C) Grocery Store	1.6 w/sf	3,000sf	4,800W
D) Retail Store	2.0 w/sf	2,500sf	5,000W
TOTAL		8,000 sf	11,750W

with 2000 square feet for future development

Figure 5-16: Chandelier Dimensions



Example 5-10: Chandelier Wattage Allowance

Question
What is the wattage allowance for a 10 cubic foot chandelier with 5-50 watt lamps in a 300 square foot entry lobby?
Answer
The wattage based on cubic feet is 10 cf x 20 w/cf = 200 watts The wattage based on the task space is 1 w/sf x 300 sf = 300 watts The wattage based on actual design watts is 250 watts. The wattage allowance for the chandelier is the smallest of the three values, or 200 watts.

C. Allowed Lighting Power - Tailored Method §146(b)3)

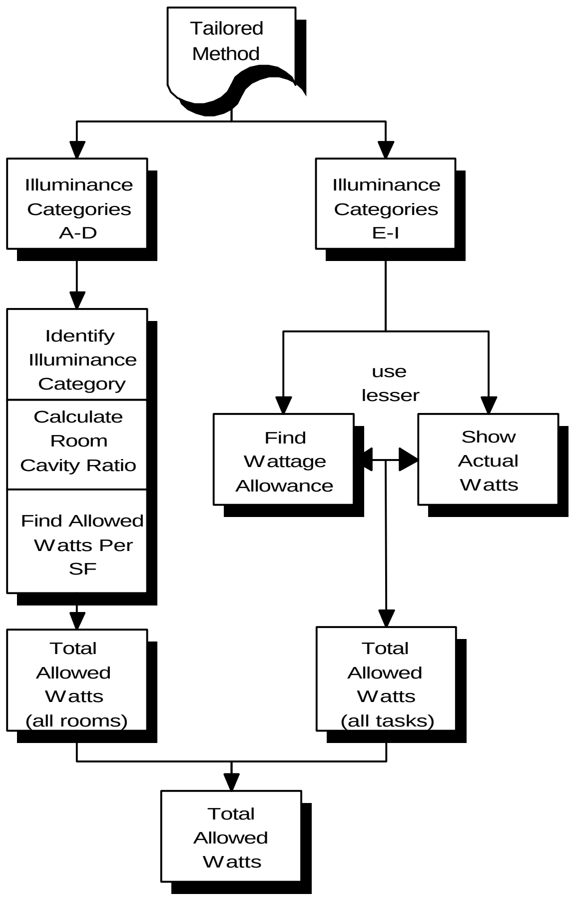
The maximum Allowed Lighting Power is determined for each space or activity when the Tailored Method is used. The difference between the Tailored Method and the Area Category Method, is that the Tailored Method takes into account each task activity in each enclosed space or task area as the basis for determining the lighting power allotment (as opposed to functional areas, which may have several different tasks). Because the Tailored Method is based on task activities, this method requires the most detail on the plans, and in some cases, requires documentation of the actual lighting tasks. The Tailored Method may allow more lighting power than the other two methods.

The task allotments are defined in terms of the illuminance category for each task. The Illuminating Engineering Society (IES) uses illuminance category and foot-candle levels for determining design lighting levels. Because the task allotments are based on the same categories as the IES design lighting levels, this method allows designers to translate their design parameters directly into allowed lighting power levels.

NOTE:
In many buildings the Tailored Method may actually result in less allowed lighting power than other methods. Larger allowances generally result from special lighting needs in a substantial portion of the building or from control credits.

The Tailored Method uses the process shown in Figure 5-17 for determining the Allowed Lighting Power.

Figure 5-17: Tailored Method Flowchart



Determining Illuminance Categories (§146(b)3.A)

The first step in identifying the Allowed Lighting Power when using the Tailored Method is to determine the illuminance category for each task. Illuminance categories are determined according to the task activity that will be performed. For each task, the appropriate illuminance category is found in Table B-10 (Appendix B), or in tables and procedures found in the IES Handbook, Applications Volume, 1987. Selection of each illumination category must be supported by a justification on the plans.

The Energy Commission has simplified the selection of illuminance categories for some specific types of tasks. These are listed in Table 5-5.

Illuminance categories A, B, C, and D are used for general lighting, and may be assigned within spaces without detailed supporting documentation. In fact, these categories may be used for allotments in spaces where the actual task areas are not yet defined based upon general plan designations such as: office, hallway, or rest room.

Selection of illuminance categories E through I require specific identification of the task area, as well as of the luminaires and wattages assigned to it. If it is determined from Table 5-5 or from Appendix B, Table B-10 that one of these categories applies to a particular task, then the next step is to determine the area of the task (see below).

In cases where the office lighting needs cannot be met using category D, private offices and workspaces receive a special lighting allotment based on the ANSI/IES RP-1, Office Lighting American National Standard Practice. These spaces are defined in Section 101 as follows:

Private Office or Work Area is an office bounded by 30-inch or higher partitions and is no more than 200 square feet.

Table 5-5: Illuminance Categories for Tasks

Illuminance Categories for Tasks	
Task Area	**Illuminance Category**
Churches:	
Altar, Ark, Reredos	E
Choir and Chancel	D
Main Worship Area	D
Pulpit, Rostrum	E
Dining	D
Office	D*
Public Area Displays	G
Sales Feature Displays	G
All Others	IES Handbook
*Special criteria if higher illuminance category needed (see text above). NOTE: All categories E and higher require consideration. See explanatory sections on following pages.	

Category E can only be applied in offices which have visually difficult tasks requiring extra illumination, and can only be used for up to 50 percent of the area of the office. The remainder of the office is calculated using 0.4 w/sf.

The criteria for determining if a task is visually difficult is based on the duration of time spent on the more difficult task. This means that the illuminance category for visual task requirements shall not be based upon an incidental task, or combination of tasks which specify the use of a given illuminance category when the incidence of these tasks totals less than two hours per working day.

A number of tasks may be visually difficult because their quality is poor. If the task quality can be improved, such tasks are not permitted to be the basis of an increased power allotment. This is especially applicable to category E tasks. The ANSI/IES RP- list the following as poor quality office tasks that are capable of being improved, and thus, do not qualify for the higher illuminance categories:

- Ditto copy, Thermal copy, poor copy and thermal printer
- Xerography, third generation and greater
- Impact printer, second carbon or later
- Typed print, second carbon or later
- Printing—6 point type
- Handwritten carbon copies
- Handwritten pencil harder than No. 2

The reason these tasks are not allowed as the basis for higher lighting levels is because efficient practices are generally available which will eliminate the higher lighting need by substituting better quality tasks. Examples of these good quality alternatives are:

- Mimeograph and xerography copy
- Impact printers with good ribbon
- Typed originals in 8 point and larger type
- Handwritten originals in No. 2 pencil or pen.

As a general rule, it is unusual for office environments other than graphic, architectural, or engineering design studios (or similar types of occupancy) to need Category E or higher illuminance levels. Applicants must provide an affidavit signed by the building owner/user that provides substantial justification for such visual "needs" and building officials should question extensive use of high level lighting requirements for common office spaces.

Example 5-11: Office Task Duration

Question

Can illuminance category "E" be used in an office because every office worker is expected to read fax transmittals and use a phone book?

Answer

This activity would not normally meet the test of two hours duration to allow use of Category "E". However, a special business that involved reading phone books on a regular basis for most of the day could be documented and allowed the higher lighting category.

Determining LPD Values

After the illuminance category is determined, the next step is to find the lighting power density (LPD), in watts per square foot (w/sf), for each category. This depends on the illuminance category, and also on the room cavity ratio (see below) for categories A through E, Table 5-7, and upon throw distance for categories F through I, Table 5-8.

Room Cavity Ratio (RCR)

The lighting level in a room is affected by the amount of light its fixtures provide and by the configuration of the room, expressed as the Room Cavity Ratio (RCR) (definition in Section 101). Since lighting fixtures are not as effective in rooms with high RCRs, the Standards allow a greater LPD to compensate for this effect in rooms with high RCRs.

For the Tailored Method, the maximum adjusted LPD assigned to illuminance categories A through E depends on the RCR of the space.

The RCR is based on the entire space bounded by floor to ceiling partitions. If a task area within a larger space is not bounded by floor to ceiling partitions, the RCR of the entire space must be used for the task area.

The RCR is calculated from one of the following formulas:

Rectangular Shaped Rooms

$$\text{RCR} = \frac{5 \times H \times (L + W)}{L \times W}$$

Where:

RCR = The room cavity ratio.

H = The room cavity height, vertical distance measured from the work plane to the center line of the lighting fixture.

L = The room length.

W = The room width.

Non-rectangular Shaped Rooms

$$\text{RCR} = \frac{[2.5 \times H \times P]}{A}$$

Where:

RCR = The room cavity ratio.

H = The room cavity height (see equation above).

A = The room area.

P = The room perimeter.

It is not necessary to calculate RCR values for rooms with an RCR less than 3.5. Rooms with RCRs higher than 3.5 are allowed higher LPDs under the Tailored Method (see Table 5-7). Table 5-6 gives typical RCR values calculated for rooms with the task surface at desk height (2.5 ft above the floor). This table is useful in assessing whether or not a room is likely to have an RCR greater than 3.5.

The LTG-5 may be used to calculate RCR values greater than or equal to 3.5. After the RCR is determined, the LPD can be found.

Table 5-6: Typical RCRs for Flush/Recessed Luminaires (Task height 2.5 ft above floor)

Room Length (ft)	Room Width (ft)				
	8	12	16	20	24
5	8.9	7.8	7.2	6.9	6.6
8	6.9	5.7	5.2	4.8	4.6
12	. . .	4.6	4.0	3.7	3.5
16	. . .	. . .	3.4	3.1	3.0
20	. . .	. . .	. . .	2.8	2.5
24	. . .	. . .	. . .	. . .	2.3
Room Cavity Height = 5.5 ft (eight feet from floor to luminaire)					
5	12.2	10.6	9.8	9.4	9.1
8	9.4	7.8	7.0	6.6	6.3
12	. . .	6.3	5.5	5.0	4.7
16	. . .	. . .	4.7	4.2	3.9
20	. . .	. . .	. . .	3.8	3.4
24	. . .	. . .	. . .	. . .	3.1
Room Cavity Height = 7.5 ft (ten feet from floor to luminaire)					

Example 5-12: RCR Calculation

Question

A private office is 12 ft wide, by 12 ft long, by 9 ft high. The lighting system uses recessed ceiling fixtures. The task surface is at desk height (2.5 ft above the floor). What is the room cavity ratio?

Answer

The room cavity height is the distance from the ceiling (center line of luminaires) to the task surface (desk height). This is 9 ft – 2.5 ft = 6.5 ft.

RCR = [5 x H x (L + W)] / L x W

RCR = [5 x 6.5 x (12 + 12)] / (12 x 12) = 5.42

LPD for Categories A, B, C, and D

The LPD allowed for each illuminance category is determined using the room cavity ratio (RCR) and Table 5-7, which show the LPD's for illuminance categories A, B, C, D (and E). Document on LTG-4, Part 1 of 3. To calculate RCR, see above formulas.

Table 5-7: Illuminance Categories A – E

Lighting Power Density (W/sf) Illuminance Categories A-E			
Illuminance Catagories	Room Cavity Ratio		
	0 to < 3.5	>=3.5 to < 7	>=7
A	0.2	0.3	0.4
B	0.4	0.5	0.7
C	0.6	0.7	1.1
D	0.99	1.24	1.49
E	2.31	2.97	3.88
Note: Interpolation is not allowed.			

Table 5-8: Illuminance Categories F - I

Lighting Power Density (W/sf) Illuminance Categories F-I		
Illuminance Category	Task Area <= 2 sf or Throw Distance > 8 ft.	Task area > 2 sf and Throw Distance <= 8 ft.
F	9.0	4.5
G	23.4	11.7
H	56.7	29.7
I	117.0	58.5

LPD for Categories E, F, G, H, and I.

The allowed lighting power density for illuminance categories E, F, G, H and I are limited to either the value obtained in Tables 5-7 or 5-8, or the actual watts of design lighting, whichever is less. The lighting must be assigned to the task area. Adjacent non-task areas must be assigned an illuminance category between A and D.

Illuminance category E is different from categories F-I because it depends upon the RCR rather than the task area or the throw distance. In all other respects, however, these categories are treated alike. Document on LTG-4, Part 2 of 3.

The task area for each category must be determined by individual task and documented on the plans. See below for the rules and special cases for **Determining Area of a Task**.

Special Cases: General Lighting

The Allowed Lighting Power Density for library and warehouse stack type installations is based on illuminance category C for bulky item warehousing and D for library shelving. The RCR for stacks is assumed to be "7," and the appropriate LPD is found in Table 5-7. See below for an additional discussion of the determination of stack lighting area.

Neither the gross sales floor area nor the gross sales wall area for retail stores are assigned illuminance categories. Instead, these areas are assigned watts per square foot allowances.

Gross sales floor area is assigned an LPD of 2.0 watts per square foot, of associated retail area, regardless of the RCR (Section 146(b)3.D and E).

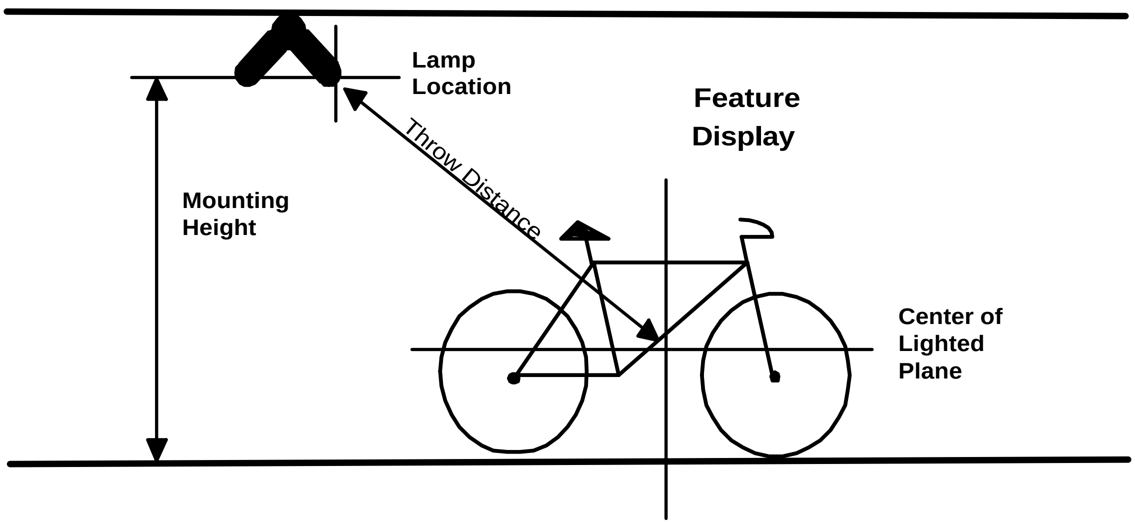
Gross sales wall area is limited to either 2.0 watts per square foot of actual wall area display, or the actual watts of design lighting, whichever is less (Section 146(b)3.D and G).

See definition of areas below in **Determining Area of a Task**.

Throw Distance. For illuminance categories F-I, the LPD allowance is higher when the throw distance from the lamp location to the display is greater than eight feet. See Figure 5-18 for an illustration of how throw distance is calculated. When there are asks illuminated by lamps with different throw distances, the shortest throw distance is used to determine the LPD allowance from Table 5-8. When track lighting is used and no fixtures are shown on the plans, the throw distance is measured perpendicular to the track from the point nearest the display.

Mounting Height. When the special circumstances of a space require that luminaires for tasks in illuminance categories A-D or E-I be mounted at a height more than 15 feet from the floor (see Figure 5-18), additional lighting power is permitted. Table 5-9 lists mounting height adjustments for various mounting heights. The appropriate multiplier is applied to the assigned LPD value from Table 5-7 or 5-8. The building department may request justification for mounting heights greater than 15 feet.

Figure 5-18: Throw Distances and Mounting Heights



When there is more than one mounting height condition, they should be separated into different task areas for purposes of applying the mounting height adjustments. The boundaries of these separate areas should be clearly shown on the plans, and the mounting height in each should also be shown with a section diagram.

Determining Area of a Task

In order to determine the Allowed Lighting Power, the task areas need to be identified. For illuminance categories A, B, C and D, the task areas are the areas of each task space that has a separate illuminance requirement. The area of each task space is determined by measuring the dimensions from inside the bounding partitions. Figure 5-19 shows a task area that has interior partitions (dotted) and bounding partitions (solid). The area is calculated by multiplying the width times the depth, as measured from the inside of the bounding partitions. The floor area occupied by the interior partitions is not included in the floor area of the function area.

Following are special rules for determining task areas in specific areas.

Office Lighting

When illuminance category E is used for private offices or work spaces, it must not be applied to more than 50 percent of the space, and the remainder of the area is allotted a 0.4 W/sf lighting power density. When Category E lighting is used, the areas must be clearly identified on the plans.

Table 5-9: Mounting Height Adjustments

Required Mounting Height	Multiplier
15 feet	1.15
16 feet	1.21
17 feet	1.47
18 feet	1.65
19 feet	1.84
20 feet or more	2.04

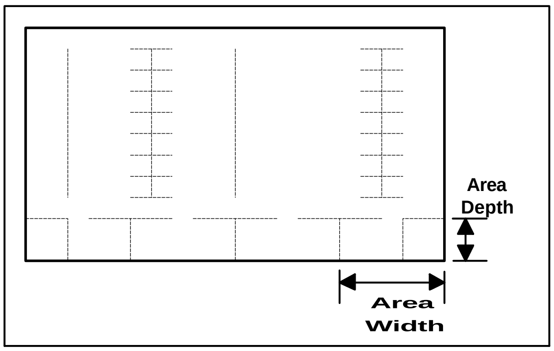
Example 5-13: Private Office

Question

The private office in Example 5-12 (RCR Calculation) is to comply under illuminance Category E. What is the Allowed Lighting Power?

Answer
The RCR is 5.4 and the area of the office is 144 sf Since 50% of the private office is allowed task E, 72 sf times 2.97 W/sf (RCR of 5.4 from Table 5-7) is 213.84 watts. The remaining private office space is calculated at 0.4 W/sf times 72 sf for a subtotal of 28.8 watts. The total Allowed Lighting Power for this space is 28.8 watts plus 213.84 watts for a total of 242.64 watts.

Figure 5-19: Calculating the Task Area



Retail and Special Display Lighting

The Tailored Method includes special provisions for retail and display lighting. The following definitions are from Standards Section 101; they are necessary to determine how the retail and display lighting provisions apply.

Display Lighting is lighting confined to the area of a display that provides a higher level of illuminance than the level of surrounding ambient illuminance.

Display, Public Areas are areas for the display of artwork, theme displays, and architectural surfaces in dining and other areas of public access, excluding restrooms and separate banquet rooms. A lighting level of Category G can be applied to these special features. This allowance cannot be used for retail applications where the highlighted feature is for sale. The public area display is the wall or floor area used for the display of artwork, theme displays, and architectural surfaces. They are limited to areas of public access, excluding restrooms and separate banquet rooms. The public area display is limited to 10 percent of the area on the plane of the display, available for each display. A space may contain both wall and floor display. Each display area must be calculated separately. These wall or floor areas are determined in a similar manner to gross sales wall or floor areas.

Display, Sales Feature is an item or items that requires special highlighting to visually attract attention and that is visually set apart from the surrounding area.

Display, Sales Feature Floor is a feature display in a retail store, wholesale store, or showroom that requires display lighting. The sales feature floor display area is confined to the actual area of display. For purposes of calculating the lighting power allowance (which is based on a Category G lighting level), this area cannot exceed 10 percent of the Gross Sales Floor Area, unless the stores gross sale area is smaller than 800 square feet in area, in which case it is permitted a Sales Feature Floor Display allowance of 1000 watts. The display areas should be clearly identified on the plans.

Display, Sales Feature Wall are the wall display areas, in a retail or wholesale space, that are in the vertical plane of permanent walls or partitions, and that are open shelving feature displays or faces of internally illuminated transparent feature display cases within the Gross Sales Wall Area. For purposes of calculating the Allowed Lighting Power, the Sales Feature Wall Display area is limited to 10 percent of the Gross Sales Wall Area at a Category G lighting level. Additionally, the areas should be clearly identified on the plans.

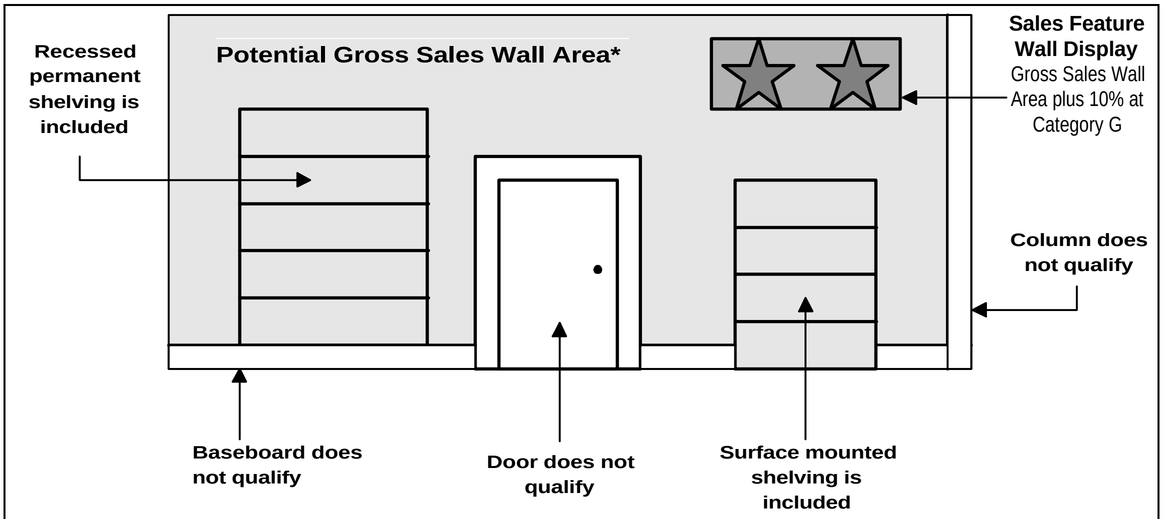
Gross Sales Floor Area is the total area (in square feet) of a retail store floor space that is (1) used for the display and sale of merchandise, or (2) associated with that function, including, but not limited to, sales transactions areas, fitting rooms and circulation areas and entry areas within the space used for display and sale. (See discussion of allotted LPD for Gross Sales Floor Area above at Special Cases: General Lighting.).

Gross Sales Wall Area is the area (in square feet) of the inside of exterior walls and permanent full height interior partitions within the gross sales floor area of a retail store that is used for the presentation of merchandise for sale, less the area of openings, doors, windows, baseboards, wainscots, mechanical or structural elements, and other obstructions preventing the use of the area for the presentation of merchandise (see Figure 5-20). The walls must be associated with the Gross Sales Floor Area. (See discussion of allotted LPD for Gross Sales Wall area above at Special Cases: General Lighting).

The Allowed Lighting Power for very valuable merchandise is 20 watts per square foot of lighted case top, or actual watts, whichever is smaller. Floor display cases, that contain jewelry and other valuable merchandise are allowed this allotment for each square foot of lighted display case counter top. To qualify for this allotment, illumination for the valuable merchandise must be provided from above the display case.

Detailed documentation should be provided on the plans that shows the placement of display cases, specific dimensions, and details of proposed lighting systems.

Figure 5-20: Gross Sales Wall Area



***The Gross Sales Wall Area is limited to the area that is actually used for merchandise display.**

Library and Warehouse Stacks

A special situation occurs when illuminating stacks of shelves in libraries, warehouses, and similar spaces. In this situation, the lighting requirements are to illuminate the vertical stack rather than the horizontal floor area (see Figure 5-21). In stack areas, as discussed above, the RCR is assumed to be greater than seven. The non-stack areas are treated normally.

Example 5-14: Stack Lighting RCR

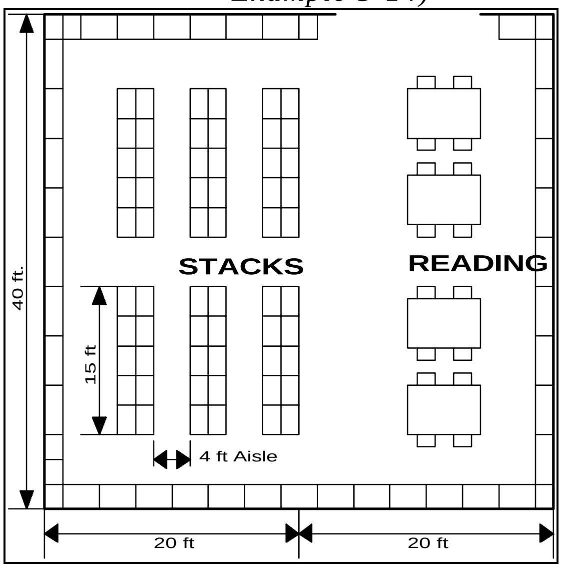
Question

How is the RCR determined for the library reading room/stack area shown in Figure 5-21

Answer

A RCR value of 7 may be assumed for the stack area. The reading area RCR is calculated based on the reading area room dimensions (20 ft x 40 ft) and on the room cavity height.

Figure 5-21: RCR for Stack Lighting (see Example 5-14)



Other Task Areas

Task areas not mentioned in the previous discussion are determined based on the actual area of each task. These other task areas must be identified on the plans submitted for permit.

Determining Allowed Watts

After the LPD and task area assigned to each space or task is established, the allowed watts may be calculated. There are two cases:

For illuminance categories A through D and for the Gross Sales Floor Area, the allowed watts are calculated simply by multiplying the LPD (watts/sf) by the area of the space (sf).

For illuminance categories E through I, Gross Sales Wall Areas and feature displays, the allowed watts are the lesser of:

a) the LPD (watts/sf) multiplied by the area of the task (sf) to obtain allotted watts, and

b) the design watts of the luminaires assigned to the task.

The sum of the allowed watts for all spaces and tasks is the building Allowed Lighting Power, in watts, as determined by the Tailored Method.

Allocation Restrictions of Task Lighting

When using the Tailored Method, the determination of task lighting is based on need. Therefore, lighting plans must be submitted that show the actual task lighting application. Task lighting allotments from walls, floors or special applications cannot be traded off for use as general lighting.

D. Simplification for Tenant Spaces

As an option, an entire tenant space can use the Complete Building Method when at least 82 percent of the permitted space is one of the primary functions listed in Table 5-4 (see Figure 5-22 and Examples 5-15 through 5-17).

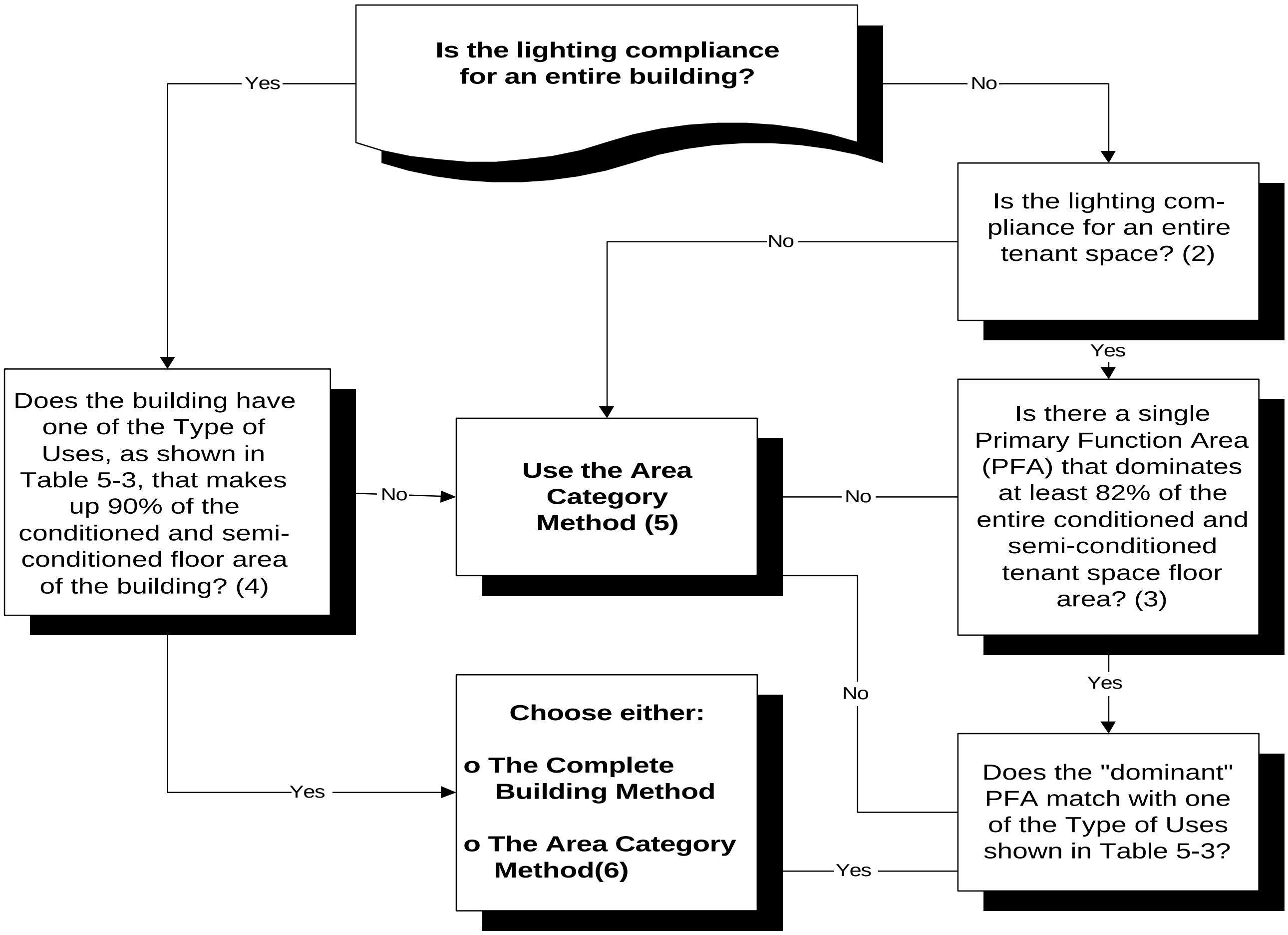
A tenant space is part of a building leased or used by a single tenant that is separated from other tenants by demising partition(s).

E. Summary

Under the prescriptive approach for lighting, one of the three methods discussed above, the Complete Building Method, the Area Category Method, or the Tailored Method, is used to determine the Allowed Lighting Power for the building. This value sets the upper limit for lighting power in the building. The next step is to calculate the Actual Lighting Power (with adjustments, if applicable). The Actual Lighting Power (adjusted) may not exceed the Allowed Lighting Power. See Section 5.2.4 for the procedures used to calculate Actual Lighting Power and its adjustments. When using Complete Building, Area Category, or Tailored Method, the lighting allotment must be based on area intended only for occupancy, or complete lighting plans must be submitted.

Figure 5-22: Lighting Power Density Calculation Flowchart

COMPLETE BUILDING METHOD AND AREA CATEGORY METHOD (1)



(1) Lighting compliance can also be achieved using the Tailored Method or the Performance Method. The lighting power portion of the Performance allowed budgets is determined by selecting the appropriate Complete Building or Area Category uses or function types, in accordance with the modeling rules shown in the flowchart above. The Tailored method may also be used to establish the lighting portion of the Performance Method allowed budget.

(2) A tenant space is a part of the building leased or used by a single entity that is separated by demising partitions from other tenants. The Complete Building Method may not be used for permits issued for partial tenant spaces. Multiple tenant spaces, when making up less than an entire building but permitted together, may each use the Complete Building Method by showing that EACH space meets the requirements of the Complete Building Method.

(3) PFA = Primary Function Area. All Primary Function Areas are listed in Table 5-4 of this Manual. The "dominant" PFA refers to the Function Area with the largest floor area among all Function Areas contained within a tenant space.

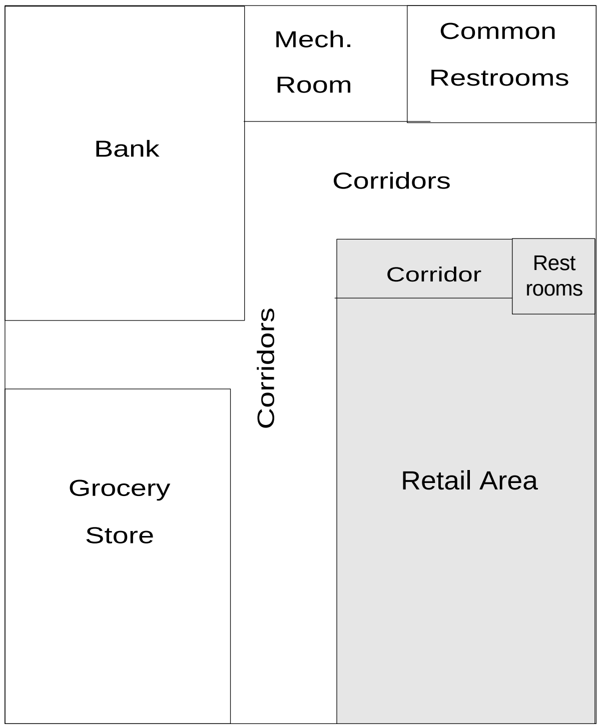
(4) Type of Use (TOU) is defined as a single type of use, as used in this Manual and listed in Table 5-3. To determine the AREA of the TOU, the following areas shall be included, provided they serve the primary use function: Lobbies, Corridors, and Restrooms.

(5) When using the Area Category Method, breakout separate Function areas into separate area categories, such as Retail Function, Corridor, Restroom, and Commercial Storage Functions.

Example 5-15: Simplified Lighting Flowchart, New Building

Question

If the figure below is a new building, what is the allowed lighting power for the entire building?



Drawing not to scale

Function	*Area*	*% Total of Area*
Non-Retail:		
Bank	*4,000*	*28%*
Grocery Store	*3,500*	*24%*
Mechanical Room	*200*	*1%*
Common Restrooms	*300*	*2%*
Common Corridors	*1,000*	*7%*
Total Non-Retail	*9,000*	*62%*
Retail:		
Retail Area	*4,700*	*32%*
Retail Restrooms	*200*	*1%*
Retail Corridors	*600*	*4%*
Total Retail	*5,500*	*38%*
Total Building	*14,500*	*100%*

Procedure

Using the flowchart in Figure 5-22:

1. Is the lighting compliance for an entire building? ***Yes***

2. Does the building have one of the Type of Uses that makes up 90 percent of the conditioned and semi-conditioned floor area of the building? ***No*** *(the largest Type of Use category is Retail which occupies 38 percent of the conditioned floor area of the entire building).*

Calculate the allowed lighting power by the Area Category Method.

Area Category Method:

Function	*Area*	*W/ft^2*	*Watts*
Bank	*4,000*	*1.4*	*5,600*
Grocery Store	*3,500*	*1.6*	*5,600*
Mechanical Room	*200*	*0.7*	*140*
Common Restrooms	*300*	*0.6*	*180*
Common Corridors	*1,000*	*0.6*	*600*
Retail Function	*4,700*	*2.0*	*9,400*
Retail Restrooms	*2000*	*0.6*	*120*
Retail Corridor	*600*	*0.6*	*360*
Total Building Lighting Power			*22,000*

Answer

The allowed lighting power is 22,000 Watts

Example 5-16: Simplified Lighting Flowchart, Alteration

Question

If the figure in Example 5-15 is an existing building and the retail store is being renovated, what is the allowed lighting power for the retail store?

Procedure

Using the flowchart in Figure 5-22:

1. Is the lighting compliance for an entire building? ***No***

2. Is the lighting compliance for an entire tenant space? ***Yes***

*3. Is there a single PFA that dominates at least 82 percent of the entire conditioned and semi-conditioned tenant space floor area? **Yes** (The permit is for one tenant (retail store), and the retail function area is greater than 82 percent of the entire retail store (4,700/5,500 = 0.855).)*

*4. Does the dominant PFA match with one of the primary Types of Uses shown in Table 5-3? **Yes***

Calculate the allowed lighting power by either the Complete Building Method, or the Area Category Method.

Complete Building Method:

Allowed lighting power is 5,500 x 1.7 - 9,350 Watts

Area Category Method:

Function	*Area*	*W/ft²*	*Watts*
A) Retail	*4,700*	*2.0*	*9,400*
B) Restrooms	*200*	*0.6*	*120*
C) Retail Corridor	*600*	*0.6*	*360*
Total Allowed Lighting Power			*9,880*

Answer

The allowed lighting power is 9,350 Watts using the Complete Building Method and 9,880 Watts using the Area Category Method.

Example 5-17: Simplified Lighting Flowchart, Retail/Grocery Combination

Question
What is the allowed lighting power for the Retail Grocery store combination in the figure below?

Drawing not to scale

Function	*Area*	*% Total of Area*
Retail	*5,750*	***63%***
Grocery	*2,150*	*23%*
Retail Office	*450*	*5%*
Restrooms	*300*	***3%***
Corridors	*550*	***6%***
Total	*9,200*	*100%*
Retail Type of Use	*6,600*	*72%*

Procedure

Using the flowchart in Figure 5-22:

*1. Is the lighting compliance for an entire building? **Yes***

*2. Does the building have one of the Type of Uses that makes up 90 percent of the conditioned and semi-conditioned floor area of the building? **No** (There are several Primary Function Areas including retail, grocery, office, restroom and storage. However, the retail, which includes retail, restrooms and corridor functions, makes up only 72 percent of the conditioned floor area. Note that the office function is a separate Type of Use and therefore excluded from the retail Type of Use calculations.)*

Calculate the allowed lighting power by the Area Category Method.

Function	*Area*	*W/ft²*	*Watts*
Retail	*5,750*	*2.0*	*11,500*
Grocery	*2,150*	*1.6*	*3,440*
Office	*450*	*1.3*	*585*
Restrooms	*300*	*0.6*	*180*
Corridor	*550*	*0.6*	*330*
Total Allowed Lighting Power			*16,035*

Answer

The allowed lighting power is 16,035 Watts.

5.2.3 Performance Approach

The performance approach provides an alternative method to the prescriptive approach for establishing the Allowed Lighting Power for the building.

Under the performance approach, the energy use of the building is modeled using a computer program approved by the Energy Commission using rules published in the Alternative Calculation Method (ACM) Manual. In this energy analysis, the standard lighting power density for the building is determined by the computer program based on occupancy type, in accordance with the Complete Building, Area Category, and Tailored rules described above(see Section 6.1 for details). This standard lighting power density is used to determine the energy budget for the building.

When a lighting permit is sought under the performance approach, the applicant uses a proposed lighting power density to determine whether or not the building meets the energy budget. If it does, this proposed lighting power density is automatically translated into the Allowed Lighting Power for the building (by multiplying by the area of the building).

If the building envelope or mechanical systems are included in the performance analysis (because they are part of the current permit application), then the performance approach allows energy trade-offs between systems that can let the Allowed Lighting Power go higher than any other method. Alternatively, it allows lighting power to be traded away to other systems, which would result in a lower Allowed Lighting Power. This flexibility in establishing Allowed Lighting Power is one of the more attractive benefits of the performance approach.

When tailored lighting is used to justify increases in the lighting load, a lower lighting load cannot be modeled for credit. The standard design building uses the lesser of allowed watts per square foot, or actual lighting power, to be installed in the building. The proposed design building uses the actual lighting power to be installed as detailed on the lighting plans. This value must be equal to, or greater than, the allowed watts per square foot.

When the Performance Approach is used, the LTG-2: Performance Approach form, or a similar form produced by an approved computer method, must be included in the compliance submittal. Refer to Section 6.1 for a more complete description of the treatment of lighting systems under the performance approach.

5.2.4 Actual Lighting Power (Adjusted)

Once the Allowed Lighting Power is determined by one of the prescriptive or performance approach, it can be compared to the Actual Lighting Power (adjusted) in the building design. The designed or Actual Lighting Power is simply the sum of the wattages of all of the lighting fixtures in the building, based on the same conditioned floor area as was used to calculate the Allowed Lighting Power.

The Actual Lighting Power may be adjusted through lighting control credits if optional automatic lighting controls are installed.

The Actual Lighting Power does not necessarily include every light in the building. There are a number of lighting applications that are exempted from the Standards limits on lighting power.

A. Exempt Lighting (§146(a)3)

The lighting applications which are exempted from the Actual Lighting Power calculation are listed below:

A. Lighting for theme parks and special effects lighting for dance floors;

B. Lighting for film studios;

C. Lighting for exhibits or for theatrical and other live performances, in exhibit, convention areas, and in hotel function areas, if the lighting is an addition to a general lighting system, and if the lighting is controlled by a multi-scene or theatrical cross-fade control station accessible only to authorized operators;

D. Specialized local lighting installed in non-lighting equipment by its manufacturer (this includes all decorative neon lighting and all signs with interior lighting);

E. In medical and clinical buildings, examination and surgical lights, low-level night lights, and lighting integral to medical equipment;

F. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment;

G. Interior lighting in refrigerated cases;

H. Lighting for plant growth or maintenance, if it is equipped with an automatic 24-hour time switch that has program backup capabilities that prevent the loss of the switch's program and time setting for at least 10 hours if power is interrupted;

I. Lighting equipment that is for sale;

J. Lighting demonstration equipment in lighting education facilities;

K. Lighting that is required for exit signs subject to Section 1012 of the UBC, if it has an efficacy of at least 40 lumens per watt and has a power factor greater than 90 percent;

L. Exit way or egress illumination that is normally off and that is subject to Section 1013 of the UBC;

M. Exit way or egress lighting whose switching is regulated by Article 3-700 of the State Electrical Code (Title 24, Part 3);

N. In hotel/motel buildings, lighting in guest rooms;

O. In high-rise residential buildings, lighting in living quarters;

P. The lighting system using the least wattage in a redundant lighting system interlocked or otherwise controlled to prohibit simultaneous operation of more than one lighting system.

Hard-wired neon lighting in signs is exempt.

B. Actual Lighting Power Calculation (§146(a))

The calculation of Actual Lighting Power is accomplished with the following steps:

1. Determine the watts for each type of fixture. This includes both the lamp and the ballast wattage. These are interdependent, so the wattage of a particular lamp/ballast combination is best determined from reputable manufacturer's test data. Default values from Table B-11 in Appendix B may be used for standard lamp and ballast combinations.

2. Determine the number of each fixture type in the design.

3. Multiply the fixture wattages by the numbers of fixtures and sum to obtain the building total Actual Lighting Power in watts.

4. Adjust for lighting control credits, if applicable (see Section 5.2.4C).

For most fixture types, this calculation is straight-forward. There are, however, a few types that require special consideration. Neon lighting that is included in the calculation of lighting power must use the transformer wattage. Track lighting and incandescent lighting must follow the guidelines below:

1. Track Lighting

Track lighting presents a special situation when calculating Actual Lighting Power, because the number and type of luminaries can be easily changed at any time. To calculate the wattage for track lights on standard voltage tracks, two values need to be determined: (a) the total luminaries wattage proposed to operate on each track; and (b) 45 watts per foot, which is 50 percent of the lighting power rating (watts) of the track by the National Electric Code (90 watts per foot). The wattage used in the calculation of Actual Lighting Power must be the larger of these two values.

Tracks serviced through permanent, installed transformers for low voltage lighting may use the volt ampere (VA) rating of the transformer as the Actual Lighting Power of the track.

Standard voltage tracks equipped with current limiters may use the actual volt-ampere (VA) rating of the current limiter as the Actual Lighting Power of the track, if:

- The current limiter is an integral part of the track and can only be replaced by manufacturer authorized technicians; and
- The VA rating of the current limiter is clearly marked on the track and is readily available for the building officials' field inspection without opening the fixture or panels.

Tracks serviced through permanent installed transformers for low voltage lighting may use the volt ampere (VA) rating of the transformer as the Actual Lighting Power of the track.

In some situations, extra length of track is desired to provide greater flexibility in locating lighting fixtures. In these cases, the designer can limit the Actual Lighting Power by providing interlock switching that limits the circuits (and therefore the electric capacity) of track lighting that can be operated simultaneously.

Track lighting for use in exhibit areas (museums, exhibit center lighting for exhibits, etc.) that meet the requirements of the exempt lighting listed in Section 5.2.4A (Item C. in list) is considered exempt lighting.

Example 5-18: Track Lighting Power

Question

What is the wattage of a six foot length of track lighting that has three 150 watt listed fixtures with 60 watt, medium base lamps proposed?

Answer

- Based on medium base socket fixtures the total wattage is 225 watts (three fixtures at 150 listed watts each times 50 percent.) See Example 5-19.
- Based on the length of track the wattage is 270 watts (6 ft x 45 w/ft).

The Actual Lighting Power of the track is the larger of the two, or 270 watts.

2. Incandescent Medium Base Sockets

Medium base sockets are typically found in fixtures that require a screw-in type lamp. They are the most common lamp base for incandescent lamps (the ordinary type of light bulb that generates light from a glowing filament), and the bases are used for a wide range of lamp wattages. These fixtures present a special situation when calculating Actual Lighting Power, because the wattage of the lamps can be easily changed at any time. To calculate the wattage for medium base fixtures, two values need to be compared: (a) the total lamp wattage proposed for the fixture, and (b) 75 watts per fixture. The wattage used in the calculation of Actual Lighting Power must be the larger of these two values.

Example 5-19: Medium Base Fixture Lighting Power

Question

What is the Actual Lighting Power of a medium base fixture, with a 60 watt lamp installed?

Answer

Based on the larger of 75 watts, or the proposed lamp (60 watts), the Actual Lighting Power is 75 watts.

Standard voltage incandescent medium base socket fixtures equipped with current limiters may use the actual volt-ampere (VA) rating of the current limiter as the Actual Lighting Power of the fixture, if:

- The current limiter is an integral part of the fixture and can only be replaced by manufacturer authorized technicians; and
- The VA rating of the current limiter is clearly marked on the fixture and is readily available for the building officials' field inspection without opening the fixture or panels.

C. Automatic Lighting Control Credits (§146(a)2)

The watts of connected lighting within the building may be adjusted to take credit for the benefits of certain types of automatic lighting controls. A list of the controls that qualify for these credits is shown in Table 5-10.

The lighting control credits reduce the Actual Lighting Power, giving a lower adjusted lighting power. This makes it easier to meet the Allowed Lighting Power requirement.

Automatic lighting controls can reduce the amount of energy used for lighting; a credit is permitted when the control types indicated in Table 5-10 are used. See also Section 5.1.2C.

In order to qualify for the power savings adjustment, the control system or device must be certified (see Section 5.2.1D), and must control all of the fixtures for which credit is claimed. At least 50 percent of the light output of the controlled luminaire must fall within the applicable type of space listed in Table 5-10. Additionally, credits may not be combined, with the exception of those listed as Combined Controls in Table 5-10 on the following page. Daylighting control credits are only available for luminaries within daylit zones, as defined in Section 5.2.1 of this manual.

5.2.5 Alterations

When altering lighting component(s) in an existing conditioned building, compliance requirements vary with the details and extent of the alterations. Some or all mandatory measures may apply, and compliance with current lighting requirements (watts/sf) may also apply. The mandatory requirements include certification of any new lamps and ballasts that are installed if they are the type regulated by the Appliance Efficiency Regulations. Any new lighting controls must meet minimum performance requirements. In addition, control and circuiting requirements (Sections 131 and 132) apply as follows:

- Independent switching within a space or room is required if ceiling height partitions are installed or moved, creating a new enclosed space.
- Bi-level illumination requirements apply if the alteration consists of rewiring and any individual enclosed space within the altered area exceeds 100 square feet and has more than 1.2 watts per square foot.
- Separate switching for daylit areas is required if the alteration involves rewiring and any individual enclosed space within the altered area exceeds 250 square feet (see **Daylit Areas**, Section 5.2.1C).
- Shut-off control requirements apply if the area in which the lighting alteration is occurring exceeds 5,000 square feet. The altered area is the area lit by the particular fixture(s) being altered. For general distribution lighting, determine the area lit using the skylight/daylit area approach (see Example 5-6). For task lighting, the area lit is expected to be narrower.
- Tandem wiring is required if the alteration involves rewiring.

> NOTE:
>
> There are exceptions and alternative methods of complying with each of these sections. For more information, refer to Section 5.2.1.

If an alteration involves replacing more than 50 percent of the lighting fixtures or results in an increase in the connected lighting load, compliance with current Standards for wattage levels is also required. When it is necessary to calculate the existing wattage to demonstrate that the alteration does not result in an increased lighting level, use the same methodology used for new lighting installations found in this section. Document both "existing" and "new" lighting power on form LTG-2.

Only those areas affected by the alteration are included in documentation. Unaltered lighting does not need to meet any requirements of the

Table 5-10: Power Savings Adjustments for Lighting Controls

Type of Control	Type of Spaces	Lighting Adjustment Factor
Occupant Sensor		
With separate sensor for each space	Any space < or = 250 sq. ft. enclosed by an opaque ceiling to floor partition; any size classroom, corridor, conference or waiting room	0.20
	Rooms of any size that are used exclusively for storage	0.60
	Rooms > 250 sq. ft.	0.10
Dimming System		
Manual	Hotels/motels, Restuarants, Auditoriums, Theaters	0.10
Multi-scene Programmable	Hotels/motels, Restuarants, Auditoriums, Theaters	0.20
Lumen Maintenence Controls	Any Space	0.05
Tuning	Any Space	0.10
Automatic Time Switch Control Device	Room < 250 sq.ft. and with timed manual override at each switch location required by §131(a), and controlling only the lights in the area enclosed by ceiling-height partitions	0.05
Combined Controls		
Occupant sensor with a separate sensor for each space used in conjuction with lumen maintenence controls	Any space < or = 250 sq.ft. and enclosed by opaque ceiling to floor partitions	0.25
Occupant sensor with programmable multi-scene dimming system	Hotels/motels, Restuarants, Auditoriums, Theaters	0.35
Occupant sensor with a separate sensor for each space used in conjunction with daylighting controls, and separate sensor for each space	Any space < or = 250 sq. ft. within a daylit area and enclosed by opaque ceiling to floor partitions	0.10*

*May be added to daylighting control credits

Daylighting Controls:			
	Window-Wall		
Glazing	<	20% to	>
VLT > or =	0.20/0.3	0.30/0.4	0.40/0.4
VLT 35% to	0/0	0.20/0.3	0.30/0.4
VLT <	0/0	0/0	0.20/0.4

Daylighting Controls:			
	% of Gross Exterior		
Glazing	<	1% to	>3
VLT > or =	0/0.3	0.15/0.4	0.30/0.4
VLT 35% to	0/0.2	0/0.3	0.15/0.4
VLT <	0/0.1	0/0.2	0/0.3

Note: Two numbers are given in the daylighting control tables, e.g. 0.20/0.30. The stepped controls, which turn lamps on and off. The second number is for dimming output continuously rather than in steps (Section 119(e)).

Standards. The basis for determining if more than 50 percent of fixtures are being replaced is the permitted space (not the building space).

NOTE: See 5.2.2.D. *Simplification for Tenant Spaces for circumstances under which the complete building method may be used for alterations.*

Semi-Conditioned Building: In an existing semi-conditioned space, the lighting alteration requirements for conditioned buildings shall apply. When a space is unconditioned and is converted to semi-conditioned no requirements apply. If an unconditioned or semi-conditioned building is conditioned then lighting, envelope and mechanical requirements for additions shall apply (see Section 2.2).

Semi-Conditioned Space is an enclosed nonresidential space that is provided with wood heating, cooling by direct or indirect evaporation of water, mechanical heating that has a capacity of 10 Btu/(hr ft^2) or less, mechanical cooling that has a capacity of 5 Btu/(hr ft^2)or less, or is maintained for a process environment as set forth in the Standards definition of DIRECTLY CONDITIONED SPACE (§101).

5.3 LIGHTING PLAN CHECK DOCUMENTS

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the recommended forms and procedures for documenting compliance with the lighting requirements of the Standards. It does not describe the details of the requirements; these are presented in Section 5.2, Lighting Design Procedures. The following discussion is addressed to the designer preparing construction documents and compliance, and to the building department plan checkers who are examining those documents for compliance with the Standards.

The use of each form is briefly described below, then complete instructions for each form are presented in the following subsections. These forms may be included in the lighting equipment schedules on the plans, provided the information is in a similar format as the suggested form.

LTG-1: Certificate of Compliance

This form is required for every job, and it is required to appear on the plans.

LTG-2: Lighting Compliance Summary

This form is required for all submittals.

LTG-3: Lighting Controls Credit Worksheet

This form should only be required when calculating control credit watts.

LTG-4: Tailored LPD Summary and Worksheet

This form should only be required when calculating the Allowed Lighting Power using the Tailored Method. Part 1 should be submitted whenever this method is used, part 2 is used for Illuminance Categories E through I, and part 3 is used for display lighting.

5.3.1 LTG-1: Certificate of Compliance

The LTG-1 Certificate of Compliance form is in two parts. Both parts must appear on the plans (usually near the front of the electrical drawings). A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the official Energy Commission forms), provided the information is the same and in a similar format.

A. LTG-1 Part 1of 2

Project Description

PROJECT NAME is the title of the project, as shown on the plans and known to the building department.

DATE is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

PROJECT ADDRESS is the address of the project as shown on the plans and as known to the building department.

PRINCIPAL DESIGNER - LIGHTING is the person responsible for the preparation of the lighting plans, one of two people who sign the STATEMENT OF COMPLIANCE (see below). The person’s telephone number is given to facilitate response to any questions that arise.

DOCUMENTATION AUTHOR is the person who prepared the energy compliance documentation. This may or may not be the principal designer (it may be a person specializing in energy standards compliance work). This person is not subject to the Business and Profession’s Code. The person’s telephone number is given to facilitate response to any questions that arise.

ENFORCEMENT AGENCY USE is reserved for building department record keeping purposes.

General Information

DATE OF PLANS is the last revision date of the plans. If the plans are revised after this date, it may be necessary to resubmit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.

BUILDING CONDITIONED FLOOR AREA has specific meaning under the Standards. Refer to Section 2.1.2A for a discussion of this definition.

The number entered here should match the floor area entered on form ENV-1

CLIMATE ZONE of the building. Refer to Appendix C.

BUILDING TYPE is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the Nonresidential Standards are designated "Nonresidential" here. It is possible for a building to include more than one building type. See Section 2.1.2B for the formal definitions of these occupancies.

PHASE OF CONSTRUCTION indicates the status of the building project described in the documents. Refer to Section 2.2 for detailed discussion of the various choices.

a. **NEW CONSTRUCTION** should be checked for all new buildings (see Section 2.2.6), newly conditioned space (see Section 2.2.2) or for new construction in existing buildings (tenant improvements, see Section 2.2.3) which are submitted for envelope compliance.

b. **ADDITION** should be checked for an addition which is not treated as a stand-alone building, but which uses Option 2 described in Section 2.2.5 Additions.

c. **ALTERATION** should be checked for alterations to existing building lighting systems. See Section 2.2.4.

METHOD OF LIGHTING COMPLIANCE indicates which method is being used and documented with this submittal:

a. COMPLETE BUILDING should be checked if the lighting system complies using the complete building method, as documented on the LTG-2 Form

b. AREA CATEGORY should be checked if the area category method, as documented on the LTG-2 form

c. TAILORED should be checked if the tailored method of lighting compliance, with supporting documentation (LTG-2 and LTG-4) is submitted.

d. **PERFORMANCE** should be checked when the performance method is used to show compliance. All required performance documentation must be included in the plan check submittal when this method is used.

Statement of Compliance

The Statement of Compliance is signed by the person responsible for preparation of the plans for the building. This person is also responsible for the energy compliance documentation, even if the actual work is delegated to someone else (the Documentation Author described above). It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the Business and Professions Code (based on the edition in effect as of April 1998), referenced on the Certificate of Compliance, are provided below:

5537. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. *This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.*

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. *This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:*

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

***6737.3.** A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.*

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person.

Lighting Mandatory Measures

This portion requests the location of notes clarifying the inclusion of the mandatory requirements. Notes should be included on the plans to demonstrate compliance with mandatory requirements of the Standards*.*

Following are prototype examples of the notes that should be rewritten to actual conditions. A note for each of the items listed should be included, even if the note states "not applicable".

Example 5-20: Sample Notes: Lighting Mandatory Measures

- **Building Lighting Shut-off**

  The building lighting shut-off system consists of an automatic time switch, with a zone for each floor: or

  the building is separately metered and less than 5,000 square feet; exempt from the shut-off requirement.

- **Override for Building Lighting Shut-off**

  The automatic building shut-off system is provided with a manual accessible override switch in sight of the lights. The area of override is not to exceed 5,000 square feet.

- **Automatic Control Devices Certified**

  All automatic control devices specified are certified, all alternate equipment shall be certified and installed as directed by the manufacturer.

- **Fluorescent Ballast and Luminaires Certified**

  All fluorescent fixtures subject to certification and specified for the projects are certified.

Example 5-20: Sample Notes: Lighting Mandatory Measures (continued)

- **Tandem Wiring for Two-Lamp Ballast's**

  All one and three lamp fluorescent fixtures are tandem wired with two (2) lamp ballast where required by *Standards* Section 132; or

  All three lamp fluorescent fixtures are specified with electronic high-frequency ballast's and are exempt from two-lamp tandem wiring requirements.

- **Individual Room/Area Controls**

  Each room and area in this building is equipped with a separate switch or occupancy sensor device for each area with floor-to-ceiling walls.

- **Uniform Reduction for Individual Rooms**

  All rooms and areas greater than 100 square feet and more than 1.0 watts per square foot of lighting load shall be controlled with Bi-level switching for uniform reduction of lighting within the room.

- **Daylit Area Control**

  All rooms with windows and skylights, that are greater than 250 square feet, and that allow for the effective use of daylight in the area shall have 50 percent of the lamps in each daylit area controlled by a separate switch; or

  The effective use of daylight throughout cannot be accomplished because the windows are continuously shaded by a building on the adjacent lot. Diagram of shading during different times of year is included on plans.

- **Control of Exterior Lights**

  Exterior mounted fixtures and served from the electrical panel inside the building are controlled with a directional photo cell control on the roof and a corresponding relay in the electrical panel.

The above notes are only examples of wording. Each mandatory measure that requires a separate note should be listed on the plans.

To verify certification, use one of the following options:

1. The Energy Hotline (see above) can verify certification of appliances not found in the above directories.

2. The Energy Commission's Web Site includes listings of energy efficient appliances for several appliance types. The web site address is www.energy.ca.gov/efficiency/appliances/.

3. The complete appliance databases can be downloaded from the Energy Commission's Internet FTP site (ftp://sna.com/pub/users/efftech/appliances). This requires database software (spreadsheet programs cannot handle some of the larger files). To use the data, a user must download the database file (or files), download a brand file and a manufacturer file and then decompress these files. Then download a description file that provides details on what is contained in each of the data fields. With these files, and using database software, the data can be sorted and manipulated.

Documenting the mandatory measures on the plans is accomplished through a confirmation statement, notes and actual equipment location as identified on the plans. The plans should clearly indicate the location and type of all mandatory control devices; such as manual switches, reduced level control, daylit area, controls, building shut-off and overrides, and exterior light controls.

B. LTG-1 Part 2

Part 2 of LTG-1 should be used to describe the lighting fixtures and control devices designed to be installed in the building. The information on this form may, with the approval of the building official, be incorporated into equipment schedules on the plans, rather than presented on the LTG-1 Part 2 form. If this is done, however, the same information should be included in one schedule in a format similar to the Energy Commission form.

Installed Lighting Schedule

CODE each luminaire type is described by name, code or type as shown on the plans.

LUMINAIRE DESCRIPTION lists the type (Incandescent, Fluorescent or High-intensity discharge) of lamp

NO. OF LAMPS, lists the number of lamps per fixture. If track lighting is used, and the fixtures are not shown on the plans, the length of track is entered in this column.

WATTS/LAMP is the listed watts per lamp. For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column. For low voltage lighting, enter the voltage ampere (VA) rating of the transformer. For any neon lighting required to be included in lighting wattage calculations, enter the transformer watts.

TYPE DESCRIPTION indicates the ballast type: Standard energy saving magnetic (S), Electronic High Frequency (E), or Other (O). If E or O ballast types are used, the exact ballast type and model number should be specified on the plans.

LUMINAIRE

NO. OF BALLAST lists the number of ballasts installed in each luminaire.

WATTS indicates the total lamp and ballast wattage.

TOTAL WATTS enter total wattage from both watts per lamp and ballast.

Mandatory Automatic Controls

The Mandatory Automatic Controls portion is where those devices to meet the mandatory control requirements are listed, that would include devices for building shut-off, individual room control and control of exterior lights.

CONTROL LOCATION lists the location(s) or room number(s) of the controls and should match the plans.

CONTROL IDENTIFICATION lists the symbol of the control and should match the plans.

CONTROL TYPE lists the type of certified control device used to meet the mandatory automatic control requirement.

SPACE CONTROLLED lists the location of controlled lights.

Typical controls may be covered by general notation.

Controls for Credit

The Controls for Credit portion is similar to the Mandatory Automatic Controls portion. The only difference is in the last column.

CONTROL LOCATION lists the location(s) or room number(s) of the controls and should match the plans.

CONTROL IDENTIFICATION lists the symbol of the control and should match the plans.

CONTROL TYPE lists the type of certified control device used to meet the automatic control requirement. Such controls are, occupant, daylight, dimming sensors etc.

LUMINAIRES CONTROLLED should list the luminaire type and quantity controlled for credit.

TYPE should use the same name as on the plans.

 # OF LUMEN should indicate the number of luminaires of that type that are controlled by the control type.

Typical controls may be covered by a general plan notation.

Notes to Field

This space is for use by the building department plans examiner to alert the field inspector to look for important inspection items.

C. Sample Form: LTG-1 Certificate of Compliance

CERTIFICATE OF COMPLIANCE (Part 1 of 2) LTG-1

PROJECT NAME		DATE
PROJECT ADDRESS		
PRINCIPAL DESIGNER-LIGHTING	TELEPHONE	Building Permit #
DOCUMENTATION AUTHOR	TELEPHONE	Checked by/Date Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA	CLIMATE ZONE

BUILDING TYPE ☐ NONRESIDENTIAL ☐ HIGH RISE RESIDENTIAL ☐ HOTEL/MOTEL GUEST ROOM

PHASE OF CONSTRUCTION ☐ NEW CONSTRUCTION ☐ ADDITION ☐ ALTERATION ☐ UNCONDITIONED (file affidavit)

METHOD OF LIGHTING COMPLIANCE ☐ COMPLETE BLDG. ☐ AREA CATEGORY ☐ TAILORED ☐ PERFORMANCE

STATEMENT OF COMPLIANCE

This Certificate of Compliance lists the building features and performance specifications need to comply with Title 24, Parts 1 and 6 of the California Code of Regulations. This certificate applies only to building lighting requirements.

The documentation preparer hereby certifies that the documentation is accurate and complete.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Lighting Designer hereby certifies that the proposed building design represented in this set of construction documents is consistent with the other compliance forms and worksheets, with the specifications, and with any other calculations submitted with this permit application. The proposed building has been designed to meet the envelope requirements contained in the applicable parts of Sections 110, 119,130 through 132, 146, and 149 of Title 24, Part 6.

Please check one:

☐ I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for its preparation; and that I am licensed in the State of California as a civil engineer or electrical engineer, or I am a licensed architect.

☐ I affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code by section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ I affirm that I am eligible under Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described as exempt pursuant to Business and Professions Code Sections 5537,5538 and 6737.1.

(These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

PRINCIPAL LIGHTING DESIGNER-NAME	SIGNATURE	DATE	LIC. #

LIGHTING MANDATORY MEASURES

Indicate location on plans of Note Block for Mandatory Measure ____________________

INSTRUCTIONS TO APPLICANT

For detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the Nonresidential Manual published by the California Energy Commission.
LTG-1: Required on plans for all submittals. Part 2 may be incorporated in schedules on plans.
LTG-2: Required for all submittals.
LTG-3: Optional. Use only if lighting control credits are taken.
LTG-4: Optional. Use only if Tailored Method is used. Parts 2 and 3 used only if applicable.

CERTIFICATE OF COMPLIANCE (Part 2 of 2) LTG-1

PROJECT NAME	DATE

INSTALLED LIGHTING SCHEDULE

Code	LUMINAIRE DESCRIPTION	LAMPS Type DESCRIPTION	LAMPS #	LAMPS Watts Per Lamp	BALLASTS Type DESCRIPTION	BALLASTS #	Luminaire (Lamp + Ballast) #	Luminaire (Lamp + Ballast) Watts	TOTAL WATTS

SUBTOTAL FROM THIS PAGE	
BUILDING TOTAL	
LESS CONTROL CREDIT WATTS (From LTG-3)	
ADJUSTED ACTUAL WATTS	

MANDATORY AUTOMATIC CONTROLS

CONTROL LOCATION (Room #)	CONTROL IDENTIFICATION	CONTROL TYPE (Auto Time Switch, Exterior, etc.)	SPACE CONTROLED	NOTE TO FIELD

CONTROLS FOR CREDIT

CONTROL LOCATION (Room # or Dwg. #)	CONTROL IDENTIFICATION	CONTROL TYPE (Occupant, Daylight, Dimming, etc.)	LUMINAIRES CONTROLLED TYPE	LUMINAIRES CONTROLLED # OF LUMINAIRES	NOTE TO FIELD

NOTES TO FIELD - For Building Department Use Only

5.3.2 LTG-2: Lighting Compliance Summary

Form LTG-2 (Lighting Compliance) should be completed and submitted with all applications, while LTG-3 (Control Credits) and LTG-4 (Tailored Method) should be included with LTG-2 only when that method is used. While these forms are not required to be on the plans (they may be submitted separately in the energy compliance package), the designer may include them in the lighting equipment schedules provided the information is in a similar format.

A. Actual Lighting Power

The Actual Lighting Power (Adjusted) is calculated by completing this form.

LUMINAIRE NAMES shall be listed by name or symbol.

DESCRIPTION should indicate a short list of the technical features.

NUMBER OF LUMINAIRES lists the quantity of each fixture type in the building. If track lighting is used, and the fixtures are not shown on the plans, the length of track is entered in this column.

WATTS PER LUMINAIRE lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track and incandescent medium base socket fixtures see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

CEC DEFAULT is a check to indicate if the wattage is a standard value from the data in Appendix B, Table B-11, or a nonstandard value. Nonstandard values must be substantiated with manufacturer's data sheets.

TOTAL WATTS is the product of the quantity of each luminaire listed times its watts per luminaire.

Subtotal the total watts for each luminaire and subtract the control credits, if any, from form LTG-3. The results are the Actual Lighting Power (Adjusted) for the building. This total cannot be greater than the Allowed Lighting Power calculated below.

B. Allowed Lighting Power

The Allowed Lighting Power is determined by calculating the maximum total watts of lighting that may be installed. There are four different methods that may be used. These methods may not be mixed in the same building permit application.

Complete Building Method

This method may only be used when plans and specifications for the entire building are included in the permit application.

BUILDING CATEGORY is taken from Table 5-3 for the occupancy of the building. If the building has a mixture of occupancies, the mixed occupancy rules determine the major occupancy of the building (the major occupancy must be at least 90 percent of the conditioned floor area). If there is not a major occupancy, this method may not be used.

WATTS PER SF for that building type is taken from Table 5-3 and entered here.

COMPLETE BUILDING AREA is the conditioned floor area of the entire building, including the conditioned floor area of minor occupancies.

ALLOWED WATTS is the product of the watts per square foot times the complete building area. This becomes the Allowed Lighting Power for the building.

Area Category Method

This method may be used when different primary function areas of a building are included in the permit application.

AREA CATEGORY is taken from Table 5-4 for the primary function of the area. If the building has a mixture of areas, each function area must be listed separately.

WATTS PER SF for that building type is taken from Table 5-4 and entered here.

AREA (SF) is the conditioned floor area of the primary function area measured from the inside of bounding partitions (Section 5.2.2 B).

ALLOWED WATTS is the product of the watts per square foot times the primary function area. This becomes the Allowed Lighting Power for the area.

The sum of the Allowed Lighting Power for each primary function area is the Allowed Lighting Power for the building.

Tailored Method

When the Tailored Method is used, the LTG-4 forms, or a similar form, must be included in the compliance submittal.

TOTAL ALLOWED WATTS is entered here from line 4, of LTG-4: Tailored LPD Summary and Worksheet, Part 1 of 3.

C. Sample Form: LTG-2 Lighting Compliance Summary

LIGHTING COMPLIANCE SUMMARY LTG-2

PROJECT NAME	DATE

ACTUAL LIGHTING POWER

LUMINAIRE NAME	DESCRIPTION	NUMBER OF LUMINAIRES	WATTS PER LUMINAIRE (Including Ballast)	CEC DEFAULT? Y	CEC DEFAULT? N	TOTAL WATTS
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	

SUBTOTAL FROM THIS PAGE	
PLUS SUBTOTAL FROM CONTINUATION PAGE	
LESS CONTROL CREDIT WATTS (From LTG-3)	
ADJUSTED ACTUAL WATTS	

If not using the CEC Default value, please provide supporting documentation.

ALLOWED LIGHTING POWER (Choose One Method)

COMPLETE BUILDING METHOD

BUILDING CATEGORY (From § 146(b) Table 1-M)	WATTS PER SF	COMPLETE BLDG. AREA	ALLOWED WATTS

AREA CATEGORY METHOD

AREA CATEGORY (From § 146(b) Table 1-N)	WATTS PER SF	AREA (SF)	ALLOWED WATTS
	TOTALS	AREA	WATTS

TAILORED METHOD

TOTAL ALLOWED WATTS (From LTG-4. or from Computer Run) ______

5.3.3 LTG-3: Lighting Controls Credit Worksheet

When certain types of automatic lighting controls listed in Table 5-10 are used, a credit is permitted. This table also lists some restrictions that must be met in order to take credit for the controls.

Lighting control credits are documented on form LTG-3. This requires a specific listing of each device that is used for credit and listing those luminaires controlled by that device.

Column A list the room where the control device is controlling luminaires.

Column B lists a description of that device.

Column C indicates where on the plan set the controls are shown.

Column D indicates the area of the room in which the controls are located.

Column E is used to indicate the room ratio for determining the daylighting control credit and is described in Section 5.2.1. The window wall ratio for the window in the room should be used for vertical daylighting configurations. The skylight well opening (at the ceiling level) to roof/ceiling area should be used for horizontal daylighting configurations.

Column F is used to indicate the visible light transmittance of the aperture. The visible light transmittance is determined in Section 5.2.1

Column G is used to document the total watts of controlled lighting in each room.

Column H is used to indicate the Power Savings Adjustment Factor for that specific control device and is obtained from Table 5-10.

Column I is the sum of Column G (Watts of Control Lighting) times Column H (Lighting Adjustment Factor).

The total Control Credit Watts (entered on LTG-3) is the sum of the Control Credit Watts in Column **I**. This credit is subtracted from the total installed watts to determine the Actual Lighting Power (Adjusted).

A. Sample Form: LTG-3 Lighting Controls Credit Worksheet

LIGHTING CONTROLS CREDIT WORKSHEET LTG-3

PROJECT NAME | DATE

WORKSHEET

A	B	C	D	E	F	G	H	I
				DAYLIGHTING				
ROOM # ZONE ID	LIGHTING CONTROL DESCRIPTION	PLANS REF.	ROOM AREA (SF)	ROOM RATIO*	GLAZING VLT	WATTS OF CONTROL LIGHTING	LIGHTING ADJUSTMENT FACTOR	CONTROL CREDIT WATTS (G X H)

PAGE TOTAL →

BUILDING TOTAL →

Enter on LTG-2: Actual lighting Power calculation

*For windows, use the Window Wall Ratio for the room. For skylights, use the Skylight-to Roof ratio for the room.

5.3.4 LTG-4: Tailored LPD Summary and Worksheet

The Tailored Method is the most detailed method of calculation for the Allowed Lighting Power. The Allowed Lighting Power is determined on the individual needs of each task. This method is appropriate for buildings that have unusual lighting needs and in some cases, can increase the Allowed Lighting Power to meet those needs. For a complete description of this method, refer to Section 5.2.2C of this Manual.

A. LTG-4: Part 1 of 3

This form should be submitted with all Tailored Method applications. It summarizes the results of the different parts of LTG-4, and includes the Allowed Lighting Power calculations for Illuminance Categories A, B, C and D.

Tailored Lighting Summary

The Allowed Watts is the summation for the building, included at the top of Part 1 of form LTG-4.

Line 1. is the buildings total allowed watts for Illuminance Categories A through D, and the Gross Sales Floor Area. This value is obtained from the bottom right corner of this form.

Line 2. is the buildings total allowed watts for illuminance categories E through I, and the Gross Sales Wall Area. This value is obtained from the Building Total entry on LTG-4, Part 2.

Line 3. is the buildings total allowed watts for display lighting. This value is obtained from the Total Watts entries on LTG-4, Part 2 and Part 3. Each display allotment is separately calculated and entered into the appropriate column on this form.

Line 4. is the sum of lines 1, 2, and 3. The Total Allowed Watts is the Allowed Lighting Power using the Tailored Method.

Tailored LPD- Illuminance Categories A, B, C, D and Gross Sales Floor Area

To complete the lower portion of Part 1 of this form, complete the following steps.

Column A lists the room number of space designation and should correspond with the plans.

Column B lists the task or activity that will occur in the room or space.

Column C lists the Illuminance Category for the room or space. This is determined by using either Table 5-5, Table B-10 of Appendix B, or the IES Handbook, Applications Volume, 1987. Additional information is included in Section 5.2.2C. of this Manual..

Column D lists the room cavity ratio (RCR) of each room or space. A RCR of less than 3.5 may be assumed for any room. Table 5-6 in Section 5.2.2C. includes the RCR of simple spaces. The LTG-5 may be used to calculate an RCR greater than or equal to 3.5.

Column E lists the actual floor area of the room or space from the plans. The area is determined by measuring from the inside of the partitions that bound the task area.

Column F lists the allowed lighting power density from Table 5-7 (Standards Table No. 1-R) using the Illuminance Category (Column C) and room cavity ratio (Column D) for each room. For Gross Sales Floor Areas, this value can be no more than 2.0 watts per square foot.

Column G is the product of the floor area times allowed lighting power density. The total for all rooms or spaces that contain task activities that fall within Illuminance Categories A through D entered in line 1 at the top of LTG-4, Part 1.

B. LTG-4 Part 2 of 3

Tailored LPD - Illuminance Categories E, F, G, H, I and Gross Sales Wall Area

To complete the upper portion of Part 2 of this form, complete the following steps.

Column A lists the task or activity that will occur in the room or space. Gross Sales Wall Areas do not include architectural features that prevent the use of the wall for the display of merchandise. See Section 5.2.2C for more information on how to calculate the areas of tasks or activities.

Column B lists the Illuminance Category for the room or space. This is determined according to Table 5-5 of Appendix B, Table B-10, Illuminance Categories, or using the IES Handbook Application Volume, 1987. Additional information is included in Section 5.2.2C. of this Manual.

Column C lists the room cavity ratio (RCR) of each room or space that requires the use of Illuminance Category E. A RCR of less than 3.5 may be assumed for any room. Table 5-6 in Section 5.2.2C. includes the RCRs of simple spaces. The LTG-5 may be used to calculate an RCR greater than or equal to 3.5.

Column D lists either the mounting height, throw distance, or both (if both are used), for the luminaires. Section 5.2.2C contains a discussion on how to determine the mounting height and throw distance of luminaires.

Column E lists the actual floor area of the room or space from the plans. The area is determined by measuring from the inside of the partitions, if any, that bound the task area.

Column F lists the allowed LPD from Table 5-9 (Standards Table No. 1-R) using the Illuminance Category (Column B), room cavity ratio for Illuminance Category E (Column C) rooms or spaces, and mounting height/throw distance adjustment factors (Column D) for display luminaires. For Gross Sales Wall Areas, this value can be no more than 2.0 watts per square foot.

Column G is the product of the floor area times allowed LPD (Column E times Column F).

Column H lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the task or activity. If more than one luminaire type is used to illuminate the task or activity, each type must be separately listed. Multiple lines on this form may be used for this list.

Column I lists the quantity of luminaires used to illuminate the task or activity. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

Column J lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

Column K is the product of the quantity of luminaires (Column I) times the watts per luminaire (Column J). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

Decorative Chandeliers and Sconces are allowed the smaller of 20.0 watts per cubic foot, one (1) watt per square foot times the area of the task space that the chandelier or sconce is in, or the actual design wattage of the chandelier or sconce. These displays may use the Illuminance Category E through I form to determine the Allowed Lighting Power for these displays.

Enter the smaller of 20.0 watts per cubic foot of chandelier or sconce volume, or one (1) watt per square foot of area that the chandelier or sconce is in Column G. If volume is used to determine the Allotted Watts in Column G, enter the area of the task space in Column D (Notes), the volume in cubic feet in Column E and the 20.0 watt per cubic foot allotment in Column F. If area was used to determine the Allotted Watts in Column G, enter the volume in Column D (Notes), the area in *Column E* and one (1) watt per square foot in column F. Enter the chandelier or sconce name in Column H, the quantity in Column I and the watts per luminaire in Column J.

Column L is the lesser of either the Allotted Watts (Column G) or the Design Watts (Column K).

The sum of the Allowed Watts in Column L is entered on Line 2, Part 1 of LTG-4.

Tailored Lighting - Public Area Displays

When public areas include feature display lighting, it must be documented according to the floor display lighting procedure established in Section 5.2.2C. To complete the lower portion of Part 2 of LTG-4, complete the following steps.

Column A lists the name of the Section 5.2.2C for definition of Public Area Displays.

Column B lists the throw distance of the display luminaires. Section 5.2.2C contains a discussion on how to determine the throw distance of display luminaires.

Column C lists the mounting height for display luminaires. Section 5.2.2C contains a discussion on how to determine the mounting height of display luminaires.

Column D lists the actual area of the display from the plans. This area must be totaled at the bottom of the column. Additional public display allowances cannot be taken for public displays exceeding 10 percent of the public area. Section 5.2.2C. contains a discussion on how to determine the area of the display.

Column E lists the allowed lighting power density from Table 5-8 using the mounting height/throw distance adjustment factors (Columns C and D) for display luminaires.

Column F is the product of the task area (Column D) times allowed lighting power density (Column E.)

Column G lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the display. If more than one luminaire type is used to illuminate the display, each type must be separately listed. Multiple lines on this form may be used for this list.

Column H lists the quantity of luminaires used to illuminate the display. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

Column I lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

Column J is the product of the quantity of luminaires (Column H) times the watts per luminaire (Column I). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

Column K is the lesser of either the Allotted Watts (Column F) or the Design Watts (Column J).

The sum of the Allowed Watts in Column K is entered on Line 3, Part 1 of LTG-4.

C. LTG-4: Part 3 of 3

Tailored Lighting - Sales Feature Floor Displays

When retail spaces include sales feature floor display lighting, it must be documented according to the display lighting procedure established in Section 5.2.2C. An allotment of 1,000 watts is permitted for sales feature floor displays in lieu of performing this calculation, if the gross sales area of the entire building is less than 800 square feet.
Complete the upper portion of Part 3 of this LTG-4, complete the following steps.

Column A lists the name of the sales feature floor display. See Section 5.2.2C for more information on the definition of Sales Feature Floor Displays.

Column B lists the throw distance of the display luminaires. Section 5.2.2C contains a discussion on how to determine the throw distance of display luminaires.

Column C lists the mounting height for display luminaires. Section 5.2.2C contains a discussion on how to determine the mounting height of display luminaires.

Column D lists the actual floor area of the display from the plans. This area must be totaled at the bottom of the column. Additional Sales Feature Floor Display allowances cannot be taken for displays exceeding 10 percent of the gross sales floor area. Section 5.2.2C contains a discussion on how to determine the area of the Sales Feature Floor Displays.

Column E lists the allowed lighting power density from Table 5-8 using the mounting height/throw distance adjustment factors (Columns C and D) for display luminaires. This allowance will always be based on Illuminance Category G.

Column F is the product of the task area (Column D) times the Illuminance Category G lighting power density (Column E.)

Column G lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the display. If more than one luminaire type is used to illuminate the display, each type must be separately listed. Multiple lines on this form may be used for this list.

Column H lists the quantity of luminaires used to illuminate the display. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

Column I lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

Column J is the product of the quantity of luminaires (Column H) times the watts per luminaire (Column I). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

Column K is the lesser of either the Allotted Watts (Column F) or the Design Watts (Column J).

Valuable Merchandise Display Cases that contain jewelry and other valuable merchandise are allowed 20.0 watts per square foot for each square foot of lighted display case counter top. These displays may use the Sales Feature Floor Display form to determine the Allowed Lighting Power for these displays.

Enter the area of the lighted display case counter top in Column D, and the 20.0 watts per square foot allotment in Column E. The area should not be included in the total Sales Feature Floor Display area. Enter the luminaire name used to illuminate the lighted display counter top in Column G, the quantity in Column H, and the watts per luminaire in Column J.

Detailed documentation must be provided on the plans that shows the placement of display cases, specific dimensions, and details of proposed lighting systems.

The sum of the Allowed Watts for Sales Feature Floor Displays in Column K is entered on Line 3, Part 1 of LTG-4.

As with all applications in Illuminance Category G, the allowed lighting watts for feature displays may not exceed the actual installed wattage. This prevents unused display lighting allotments from being used in other areas of the store.

Tailored LPD - Sales Feature Wall Displays

When retail spaces include sales feature wall display lighting, it must be documented according to the display lighting procedure established in Section 5.2.2C. To complete the lower portion of Part 3 of this form, complete the following steps.

Column A lists the name of the sales feature wall display. See Section 5.2.2C for more information on the definition of Sales Feature Wall Displays.

Column B lists the throw distance of the display luminaires. Section 5.2.2C contains a discussion on how to determine the throw distance of display luminaires.

Column C lists the actual wall area of the display from the plans. This area must be totaled at the bottom of the column. Additional Sales Feature Wall Display allowances cannot be taken for displays exceeding 10 percent of the gross sales wall area. Section 5.2.2C contains a discussion on how to determine the area of the Sales Feature Wall Displays. The Gross Sales Wall Area is limited to the area actually used for display.

Column D lists the allowed lighting power density from Table 5-8 using the mounting throw distance adjustment factors (Columns B and C) for display luminaires. This allowance will always be based on Illuminance Category G.

Column E is the product of the task area (Column C) times allowed lighting power density (Column D.)

Column F lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the display. If more than one luminaire type is used to illuminate the display, each type must be separately listed. Multiple lines on this form may be used for this list.

Column G lists the quantity of luminaires used to illuminate the display. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

Column H lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

Column I is the product of the quantity of luminaires (Column G) times the watts per luminaire (Column H). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

Column J is the lesser of either the Allotted Watts (Column E) or the Design Watts (Column I).

The sum of the Allowed Watts for Sales Feature Wall Displays in Column J is entered on Line 3, Part 1 of LTG-4.

As with all applications in Illuminance Category G, the allowed lighting watts for feature displays may not exceed the actual installed wattage. This prevents unused display lighting allotments from being used in other areas of the store.

D. Sample Form: LTG-4 Tailored LPD Summary and Worksheet

TAILORED LPD SUMMARY and WORKSHEET (Part 1 of 3) LTG-4

PROJECT NAME	DATE

TAILORED LPD SUMMARY

1. Watts for Illuminance Categories A-D (from column G below) → ______ WATTS

2.Watts for Illuminance Categories E-I (from LTG-4 Part 2) → ______ WATTS

3. Watts for Display Lighting (from LTG-4 Parts 2 & 3)

______ + ______ + ______ = ______ WATTS

Public Area Display | Sales Feature Floor Display | Sales Feature Wall Display

4. Total Allowed Watts (lines 1+2+3) → ______ WATTS

TAILORED LPD - Illuminance Categories A, B, C and D and Gross Sales Floor Area

A	B	C	D	E	F	G
ROOM NUMBER	TASK/ACTIVITY	ILLUMINANCE CATEGORY	ROOM CAVITY RATIO	FLOOR AREA	ALLOWED LPD	ALLOWED WATTS (E X F)
			PAGE TOTAL →			
			BUILDING TOTAL →			
				SF		WATTS

TAILORED LPD SUMMARY and WORKSHEET (Part 2 of 3) LTG-4

PROJECT NAME	DATE

TAILORED LPD - Illuminance Categories E, F, G, H, I and Gross Sales Wall Area

A	B	C	D	E	F	G	H	I	J	K	L
				ALLOTTED WATTS			DESIGN WATTS				
TASK / ACTIVITY	Illum. Cat.	RCR (If E)	Notes*	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (E X F)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (I X J)	**ALLOWED WATTS** (Min. G or K)

* Enter Mounting Height or Throw Distance if applicable.

PAGE TOTAL →

BUILDING TOTAL →

TAILORED LPD - Public Area Displays

A	B	C	D	E	F	G	H	I	J	K
			ALLOTTED WATTS			DESIGN WATTS				
TASK / ACTIVITY	THROW DISTANCE	MOUNT. HEIGHT	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (E X F)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (H X I)	**ALLOWED WATTS** (Min. F or J)

TOTAL AREA PUBLIC DISPLAYS ____ SF

TOTAL ____ WATTS

PLANE OF PUBLIC DISPLAY AREA ____ X 0.1 = ____ MAXIMUM AREA PUBLIC DISPLAYS (SF)

TAILORED LPD SUMMARY and WORKSHEET (Part 3 of 3) LTG-4

PROJECT NAME	DATE

TAILORED LPD - Sales Feature Floor Displays

A	B	C	D	E	F	G	H	I	J	K
			ALLOTTED WATTS			DESIGN WATTS				
TASK / ACTIVITY	THROW DISTANCE	MOUNT. HEIGHT	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (D X E)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (H X I)	**ALLOWED WATTS** (Min. F or J)

TOTAL AREA FLOOR DISPLAYS ______ SF TOTAL WATTS ______

GROSS SALES FLOOR AREA ______ X 0.1 = ______ MAXIMUM AREA FLOOR DISPLAYS (SF)

TAILORED LPD - Sales Feature Wall Displays

A	B	C	D	E	F	G	H	I	J
		ALLOTTED WATTS			DESIGN WATTS				
TASK ACTIVITY	THROW DISTANCE	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (C X D)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (G XH)	**ALLOWED WATTS** (Min. E or I)

TOTAL AREA WALL DISPLAYS ______ SF TOTAL WATTS ______

GROSS SALES WALL AREA ______ X 0.1 = ______ MAXIMUM AREA WALL DISPLAYS (SF)

5.3.5 LTG-5: Room Cavity Ratio Worksheet (≥3.5)

Form LTG-5 is an optional form only to be used in conjunction with the Tailored Method and form LTG-4. LTG-5 documents the calculation of room cavity ratios (RCRs) which are greater than or equal to 3.5 for spaces in illuminance categories A-E.

Rooms in the building which are relatively large generally have a high RCR. If the RCR is greater than or equal to 3.5, a higher LPD is allowed (see Table 5-7). If the RCR is less than 3.5, it does not need to be included on this form.

The form has two sections: **Rectangular Spaces** is for rooms with four 90° walls, and **Non-rectangular Spaces** is for all other room types (including oblique four walled and circular rooms).

A. Rectangular Spaces

Column A lists each rooms number, and should correspond to the plans.

Column B lists the task/activity description for the room. If the room has multiple tasks or activities, use the dominant activity for the room in this column.

Column C lists the Length (L) of the room, measured in feet, from the interior surfaces of opposing walls. The length is typically the longest distance between two parallel walls in the room.

Column D lists the Width (W) of the room, measured in feet, from the interior surfaces of opposing walls. The width is typically the smallest distance between two parallel walls in the room.

Column E lists the vertical distance, measured in feet, from the work plane to the center line of the lighting fixture. This measurement is called the Room Cavity Height (H).

Column F is 5 times the product of the Room Cavity Height H (from Column E) and the sum of the room Length and Width L (from Column C plus W from Column D), all divided by the Room Area L (from Column C) times Room Width (W from Column D). This quantity is the RCR and should be entered in Column D of Part 1 of LTG-4 for tasks with illuminance categories A-D or in Column C of the top section of Part 2 of LTG-4 for tasks with illuminance category E.

B. Nonrectangular Spaces

Column A lists each rooms number, and should correspond with the plans.

Column B lists the area or activity description for the room. If the room has multiple tasks or activities, use the dominant activity for the room in this column.

Column C lists the interior Area (A) of the room in square feet. This should be determined by whatever means appropriate for the shape of the room.

Column D lists the Room Perimeter (P) measured in feet along the interior surfaces of the walls which define the boundaries of the room. For rooms with angled walls, this is the sum of the interior lengths of each wall in the room. For circular rooms, This is the interior radius of the room, squared, times pi (3.413).

Column E lists the vertical distance, measured in feet, from the work plane to the center line of the lighting fixture. This measurement is called the Room Cavity Height (H).

Column F is 2.5 times the product of the Room Cavity Height H (from Column E) and Room Perimeter P (from Column D), all divided by the Room Area A (from Column C). This quantity is the RCR and should be entered in Column D of Part 1 of LTG-4 for tasks with illuminance categories A-D or in Column C of the top section of Part 2 of LTG-4 for tasks with illuminance category E.

C. Sample Form: LTG-5 Room Cavity Ratio Worksheet (RCR ≥ 3.5)

ROOM CAVITY RATIO WORKSHEET (RCR ≥ 3.5) LTG-5

PROJECT NAME		FOR ENFORCEMENT AGENCY USE ONLY	
DOCUMENTATION AUTHOR	DATE	PLAN CHECKED BY	DATE

RECTANGULAR SPACES

A Room Number	B Task/Activity Description	C Room Length (L)	D Room Width (W)	E Room Cavity Height (H)	F Room Cav. Ratio 5 x H x (L+W) / (L x W)

NON-RECTANGULAR SPACES

A Room Number	B Task/Activity Description	C Room Area (A)	D Room Perimeter (P)	E Room Cavity Height (H)	F Room Cav. Ratio 2.5 x H x P /A

5.4 LIGHTING INSPECTION

The electrical building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the LTG-1 Certificate of Compliance form printed on the plans (See Section 5.3.1). Included on the LTG-1 are "Notes to Field" that are provided by the plans examiner to alert the field inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I.

Chapter 5 Index

A

Accessibility · 10
Actual Lighting Power · 1, 3, 9, 25, 37, 41, 42, 43, 44, 55, 58
Actual Lighting Power Calculation · 42
Advanced Lighting Guidelines · 21
Agricultural · 49, 50
Allotted Watts · 61, 62, 63, 64
Allowed Lighting Power · 1, 3, 4, 25, 26, 27, 28, 29, 30, 33, 34, 35, 36, 37, 41, 44, 47, 55, 56, 60, 61, 63
Allowed Lighting Power Density · 33
Allowed Watts · 26, 60, 62, 63, 64
Alterations · 1, 44
Alternative Calculation Method (ACM) · 41
Annunciated · 5, 9
Appliance Efficiency Regulations · 21, 44
Application · 61
Arcades · 8, 28
Area · 1, 2, 3, 4, 5, 6, 7, 8, 10, 13, 25, 26, 27, 28, 29, 30, 33, 34, 37, 38, 39, 40, 41, 51, 55, 62, 68
AREA CATEGORY · 38, 48, 55
Area Category Method · 1, 2, 3, 4, 7, 26, 27, 28, 29, 37, 38, 39, 40, 55
Area Controls · 1, 10, 51
Area of a Task · 33, 34
Automatic Daylighting Controls · 20
Automatic Lighting Control Credits · 9, 44
Automatic Time · 9, 20

B

Ballasts · 1, 21
Bank/financial Institution · 7
Basic Lighting Concepts · 1, 3
Building · 1, 2, 5, 7, 25, 26, 37, 38, 39, 40, 41, 46, 50, 55, 60
Building lighting shut-off · 50
Business and Professions Code · 48

C

California Code of Regulations · 49
Captive-Key Override · 9
Category E · 31, 34, 61
Category G · 35, 63, 64
CEC DEFAULT · 55
Certificate of Compliance · 47, 48, 53, 70
Certified Ballasts XE "Ballasts" and Luminaires · 21
Chandelier · 5, 6, 29
Churches · 30
Classroom · 7
Commercial · 7, 8, 27, 28, 38
Complete Building Approach · 26
COMPLETE BUILDING AREA · 55
Compliance · 1, 3, 55
Control Credit Watts · 58
Control Credits · 1, 55
Control Devices · 1, 9, 19, 50
Control of Exterior Lights · 51
Controls · 1, 11, 16, 44, 52
Controls for Credit · 52
Convention · 7, 27
Corridors · 17, 27, 28, 38, 39, 40

D

DATE OF PLANS · 48
Daylit Area · 1, 5, 11, 12, 13, 14, 15, 44, 51
Density · 25, 38
Design Watts · 62, 63, 64
Determining Allowed Watts · 37
Determining Illuminance Categories · 30
Dimensions · 29
Directory of Automatic Lighting Control Devices · 19
Display Cases · 63
Display Lighting · 1, 4, 5, 19, 35
Display, Public Areas · 35
Documentation · 48
Documentation Author · 48

E

Effective Aperture · 5, 12, 13, 14, 16
Entire Building · 2, 5
ENV-1 · 48
Exempt Lighting · 1, 41
Exercise · 7, 27
Exterior Lights · 1, 19

F

Feature Displays · 30
Floor Area · 35

G

Garages · 49, 50
General Commercial · 7, 27
General Lighting · 3, 33, 35, 36
Glazing · 13
Grocery Store · 7, 27, 28, 39

Gross Exterior Roof Area · 13
Gross Sales Floor Area · 35, 36, 37, 60
Gross Sales Wall Area · 5, 35, 36, 37, 60, 61, 64
Guest Room · 1, 22

H

High Bay · 5, 7, 27
Hotel Function Area · 7, 27
Hotel Lobby · 8, 27
Hotel/Motel · 22, 23, 24

I

IES Handbook · 30, 60, 61
Illuminance Categories · 30, 33, 47, 60, 61
Illuminating Engineering Society (IES) · 29
Industrial · 7, 8, 27, 28
Inspection · 1, 2, 70
Installed Lighting Schedule · 52

L

Lighting · 1, 2, 3, 4, 6, 7, 9, 10, 19, 21, 22, 23, 24, 25, 27, 28, 37, 38, 39, 40, 41, 42, 43, 45, 47, 50, 51, 55, 56, 58, 60, 62
Lighting Compliance Approaches · 2
Lighting Compliance Summary · 47, 55, 56
Lighting Controls · 1, 9, 45, 47, 58
Lighting Controls Credit Worksheet · 47, 58
Lighting Energy Use · 2
Lighting Mandatory Measures · 50, 51
Lighting Plan Check Documents · 1, 2
Lighting Systems · 1
Lighting Trade-off · 3, 4
Lighting Zone · 9
Lobby · 8, 27
LTG-1 · 1, 47, 52, 53, 61, 62, 63, 64, 70
LTG-2 · 1, 41, 44, 47, 48, 55, 56
LTG-3 · 1, 47, 55, 58
LTG-4 · 1, 32, 33, 47, 48, 55, 56, 60, 61, 62, 63, 64, 68
LTG-5 · 1, 32, 60, 61, 68
Lumen Maintenance Device · 9
Luminaries · 22, 25

M

Malls · 8, 28
Mandatory Automatic Controls · 52
Mandatory Measures · 1, 10
Manual Switches · 11
Mechanical Room · 7, 28, 39
Medical · 8, 26, 28
Medium Base Sockets · 43
Mounting Height · 33, 34
Mounting Height Adjustments · 34
Multi-Scene Dimming System · 9
Museum · 8, 27, 28

N

National Electric Code · 42
Newly Conditioned Space · 5
Notes to Field · 53, 70
NUMBER OF LUMINAIRES · 55

O

Occupancy · 1, 7, 26
Office Lighting · 30, 34
Override · 11, 18, 50

P

Performance Approach · 1, 3, 41
PHASE OF CONSTRUCTION · 48
Photocell · 21
Power Savings Adjustment Factor · 58
Prescriptive Approach · 1, 25
Primary Function Areas · 38, 40
Printing · 31
Public Areas · 6, 10

R

Rectangular Shaped Rooms · 32
Reduced Flicker · 6
Repair · 7, 27
Residential Standards · 22
Restaurant · 8
Restroom · 8, 38
Retail · 8, 28, 35, 38, 39, 40
Room Cavity Height · 68
Room Cavity Ratio (RCR) · 6, 31
Room Switching · 10
Room Width · 68

S

Sales Feature Floor Display · 35, 62, 63
Sconces · 28, 61
Scope and Application · 1
Security or Emergency · 10
Semi-Conditioned Space · 46
Shut-off · 11, 18, 44

Skylight · 6, 13, 14, 15, 16
Stack Lighting · 36, 37
Statement of Compliance · 48

T

Tailored Lighting Summary · 60
Tailored Method · 1, 2, 4, 25, 29, 30, 32, 35, 37, 38, 47, 55, 56, 60, 68
Tandem Wiring · 1, 19, 20, 51
Task Area · 30, 35, 37
Task Lighting · 37
Tenant · 1, 37, 46
Theaters · 28
Throw Distance · 6, 33, 34
Total Allowed Lighting Power · 40
TOTAL ALLOWED WATTS · 56
TOTAL WATTS · 52, 55
Track Lighting · 42, 43
Trade-offs · 4
Tuning · 10

U

UBC · 8, 42

V

Valuable Merchandise · 63
Very Valuable Merchandise · 6
Visible Light Transmittance · 6, 13, 14

W

Wall · 5, 13, 35, 36, 63, 64
Wall Area · 13, 35
Well Index · 6, 13, 15, 16
Wholesale · 9, 28
Window Wall Ratio · 6, 13
Windows · 13

TOPICS

Chapter 6: Special Topics

6.0 CHAPTER OVERVIEW

This chapter provides more complete illustrations of how the *Standards* apply to items that involve all disciplines: envelope, mechanical and lighting. This includes the performance approach, hotel/motel compliance, and high-rise residential compliance.

Section 6.1 summarizes the Performance Approach. It includes a discussion of computer methods and how compliance is shown with a computer method, the procedures involved in determining the energy budget and the proposed building's energy use, and how to plan check performance compliance.

Chapter Contents

6.0 Summary 6-1

6.1 Performance Approach 6-2

- 6.1.1 Summary 6-2
- 6.1.2 Performance Concepts 6-2
  - A. Approval of Computer Programs 6-2
  - B. The Energy Budget 6-3
  - C. Compliance With a Computer Method 6-4
  - D. Compliance Procedure 6-5
  - E. Application Scenarios 6-5
  - F. Professional Judgment 6-8
- 6.1.3 Analysis Procedures 6-9
  - A. Energy Budget 6-9
  - B. Source Energy Use 6-10
- 6.1.4 Performance Plan Check Documents 6-11
  - A. PERF-1: Performance Certificate of Compliance 6-14
  - B. ENV-1: Envelope Compliance Summary 6-14
  - C. ENV-3: Construction Assemblies 6-14
  - D. EXISTING-ENV: Performance Method 6-14
  - E. MECH-1: Mechanical Compliance Summary 6-14
  - F. MECH-2: Mechanical Equipment Summary 6-15
  - G. MECH-3: Mechanical Compliance Summary/ Mechanical Ventilation 6-14
  - H. LTG-1: Lighting Compliance Summary 6-14
- 6.1.5 Performance Inspection 6-14

6.2 Hotels and Motels 6-15

- 6.2.1 Introduction 6-15
- 6.2.2 Hotel/Motel Compliance Approaches 6-15
- 6.2.3 Basic Hotel/Motel Concepts 6-15
- 6.2.4 Hotel/Motel Compliance 6-15
  - A. Mandatory Measures 6-15
  - B. Prescriptive Compliance 6-16
  - C. Performance Compliance 6-17
- 6.2.5 Hotel/Motel Plan Check Documents 6-17
- 6.2.6 Hotel/Motel Inspection 6-17

6.3 High-rise Residential 6-17

- 6.3.1 Introduction 6-17
- 6.3.2 High-rise Residential Compliance Approaches 6-17
- 6.3.3 Basic High-rise Residential Concepts 6-18
- 6.3.4 High-rise Res. Compliance 6-18
  - A. Mandatory Measures 6-18
  - B. Prescriptive Compliance 6-18
  - C. Performance. Compliance 6-19
- 6.3.5 High-rise Res. Plan Check Documents 6-19
- 6.3.6 High-rise Res. Inspection 6-19

6.4 Sample Forms 6-19

Section 6.2 is a discussion of Hotel/Motel buildings and how compliance is demonstrated for those occupancies.

Section 6.3 is a discussion of High-rise Residential buildings and how compliance is demonstrated for those occupancies.

6.1 PERFORMANCE APPROACH

6.1.1 Summary

This section explains the use of approved public domain and *Alternative Calculation Method* (ACM) computer programs to show compliance with the annual energy budget requirement of the *Standards.* The computer methods represent one of the basic compliance paths explained in Chapter 1.

Performance Concepts (Section 6.1.2) outlines the basis of the computer method approach and the ACM approval process for the use of a computer program with the *Standards.* The following section summarize the compliance procedure with computer methods.

Section 6.1.2 describes the concepts and procedures involved in using the performance approach. Section 6.1.3 describes analysis procedures used to demonstrate compliance, including the rules used to generate the annual energy budget. Section 6.1.4 outlines and illustrates the plan check documents required when using the performance approach.

This chapter should not be construed as a substitute for the compliance supplement of any particular approved computer program.

6.1.2 Performance Concepts

The Warren-Alquist Act calls for the establishing "performance standards" that predict and compare the source energy use of buildings. Because of their relative accuracy in analyzing the annual energy use of different building efficiency measures, computer programs are the basis of the performance standards.

A computer program (alternative calculation method (ACM)) cannot be used for demonstrating compliance with the *Standards* unless the ACM, the capability tests, and the vendor's certification are reviewed and approved by the Energy Commission. The programs simulate or model the thermal behavior of buildings and the interaction of their space conditioning, lighting and service water heating systems. The calculations include:

- Heat gain and heat loss through walls, roof/ceilings, floors, windows, and skylights.
- Solar gain from windows, skylights, and opaque surfaces.
- Heat storage effects of different types of thermal mass.
- Building operating schedules for people, lighting, equipment and ventilation.
- Space conditioning system operation including equipment part load performance.

The prescriptive requirements were derived from the results of building energy analysis studies using the reference computer program, DOE.

Computer methods are generally the most detailed and flexible compliance path. The energy performance of a proposed building design can be calculated according to actual building geometry and site placement. Credit for certain conservation features, such as a daylit atrium, cannot be taken in the prescriptive approach, but could be evaluated with an approved computer program.

A. Approval of Computer Programs

For any computer program (alternative calculation method) to be used for compliance with the *Standards*, the program must first be approved by the Energy Commission. Approval involves the demonstration of minimum modeling capabilities, required input and output, and adequate user documentation. The program must be able to:

- Automatically calculate the custom energy budget.
- Calculate the energy use of the proposed design in accordance with specific fixed and restricted inputs.
- Print the appropriate standardized compliance forms with the required information and format if

and only if a proposed building complies. Other reports that do not resemble forms may be printed for noncomplying buildings.

Input and output requirements and modeling capabilities are tested by using the program to calculate the energy use of certain prototype buildings under specific conditions, and the results are compared with the results from a reference computer program following the specified reference methodology. These tests and testing criteria do not allow the approval of an ACM that indicates compliance for a building that the reference method indicates does not comply with the *Standards*.

The Energy Commission approves the alternative calculation method according to the procedures outlined in Section 10-108 through 10-110 of the *California Code of Regulations*, Title 24, Part 1. The procedures are detailed in the *Alternative Calculation Methods Approval Manual for the Energy Efficiency Standards for Nonresidential Buildings, High-rise Residential Buildings and Hotel/Motels (ACM Approval Manual)*. The Energy Commission periodically updates a listing of approved computer programs that may be obtained from the Publications Office, by calling the Energy Commission's Hotline at (800) 772-3300, or by accessing the Energy Commission's Web Site (www.energy.ca.gov/ efficiency).

B. The Energy Budget

The energy budget that a building must comply with is composed of three basic components: space conditioning, lighting, and water heating. Space conditioning is further broken into space heating, space cooling, HVAC fans and pumps, and receptacle. It is expressed in source Btu per square foot of conditioned floor area per year (*Standards* §141(b)).

A building complies with the *Standard* if the predicted source *energy use* of the proposed design is the same or less than the annual *energy budget* of the standard design. The energy budget includes a space conditioning budget, lighting budget and water heating budget. The budget for space conditioning varies according to specific characteristics of the proposed building design outlined below.

The energy budget is dependent on how a building is oriented, and the budget will vary with actual building orientation. Other variables that affect the energy budget include:

- Conditioned floor area
- Conditioned volume
- Gross exterior surface area
- Space conditioning system type
- Occupancy type
- Climate zone

Assumptions used by the computer programs in generating the energy budget are explained in detail in the *ACM Approval Manual* , but are based on the prescriptive requirements of the *Standards.* The standard lighting power density for the building is determined by the program based on occupancy type, in accordance with the Complete Building, Area Category, and Tailored rules described in Chapter 5, Section 5.2.2.

The Standard Design and Proposed Design for a building is summarized in an Annual Source Energy Use Summary on the PERF-1: Performance Certificate of Compliance form, described in Section 6.1.4B and illustrated in Figure 6-1. The Standard Design is calculated according to the rules and assumptions in the *ACM Approval Manual*, and represents the total allowable energy budget for the building. The Proposed Design must be equal to or less than that of the energy budget for the building to comply.

Figure 6-1: Annual Source Energy Use Summary (Sample of PERF-1, Part 2 of 3)

ANNUAL SOURCE ENERGY USE SUMMARY (kBtu/sf-yr)			
ENERGY USE BY COMPONENT	STANDARD DESIGN	PROPOSED DESIGN	COMPLIANCE MARGIN
SPACE HEATING			
SPACE COOLING			
FANS/PUMPS			
LIGHTS			
WATER HEATING			
RECEPTACLE			
TOTAL			

C. Compliance With a Computer Method

Each approved computer program automatically generates an *energy budget* by calculating the annual energy use of the standard design, a version of the proposed building incorporating all the prescriptive features.

Although any single component of the energy use may be higher than the equivalent component in the energy budget, the total combined energy use of the Proposed Design must be less than or equal to the Standard Design. This way, trade-offs can be made between space conditioning, lighting and service water heating energy use. See Section 6.1.2E for restrictions of trade-offs.

Example 6-1: Performance Trade-offs

Question

If a PERF-1 (see Figure 6-1) shows that the proposed energy use of the "HVAC Fans and Pumps" exceeds the standard design energy budget, but the total energy use is less than the energy budget, does the building still comply?

Answer

Yes. More fan energy is being used by the proposed design, but the "Total" proposed energy use is less than the "Total" standard design energy budget, therefore the building complies.

D. Compliance Procedure

Any approved computer program may be used to comply with the *Standards.* The following steps are a general outline of the typical compliance procedure:

1. All detailed data for the building component or components must be collected including glazing, wall, door, roof/ceiling, and floor areas, construction assemblies, shading coefficients, mass characteristics, equipment specifications, lighting, and service water heating information from the drawings and specifications. Section 6.1.3B contains more detailed information on the required computer program inputs.

   Although most computer programs require the same basic data, some information, and the manner in which it is organized, may vary according to the particular program used. *Refer to the compliance supplement that comes with each program for additional details.*

   Be sure that the correct climate zone has been selected for the building site location (see Appendix C).

2. The program user has the option of using default U-values based on the tables contained in Appendix B, Table B-7. If default U-values for wall, roof/ceiling, and floor/soffit are not used, prepare the appropriate ENV-3 forms for the various proposed construction assemblies either through the use of the program or by a hand calculation.

3. Prepare an input file that describes the other thermal aspects of the proposed design according to the rules described in the program's compliance supplement.

   Input values and assumptions must correctly correspond to the proposed design and conform to the required mandatory measures described in Chapters 3, 4 and 5.

4. Run the computer program to automatically generate the energy budget of the standard design and calculate the energy use of the proposed design.

The building complies if the total energy use of the proposed design is the same or less than the standard design energy budget.

> NOTE:
>
> When creating any computer input file, use the space provided for the project title information to concisely and uniquely describe the building being modeled. User-designated names should be clear and internally consistent with other buildings being analyzed in the same project. Title names and explanatory comments should assist individuals involved in both the compliance and enforcement process.

E. Application Scenarios

Compliance with the performance approach can be done whenever compliance is demonstrated for each permit application. Each application for permit can be either a prescriptive or performance application. Because of this, the following procedures are developed in the *ACM Approval Manual* to limit the use of historical documentation.

Whole Building Compliance

Whole buildings are projects involving buildings where the applicant is applying for permits, and submits plans and specifications for all the features of the building (envelope, mechanical, lighting and service water heating). This could be a first time tenant improvement that involves envelope, mechanical and lighting compliance, or a complete building, where plans and specifications for the entire building are being submitted for permit.

When a whole building is modeled using the performance approach, trade-offs can be made between the envelope, space conditioning, service water heating, and lighting systems that are included in the permit application.

Compliance by Permit Stage

Compliance with only one or more building *permit stages* can be done using the performance approach. A *permit stage* is a portion of a whole building permit: either envelope, mechanical, or electrical. *Standards* §141(b) states that only the features of the building that are included in the building permit application can be modeled. This means that trade-offs in energy use are limited to include only those features included in the building permit application.

There are two basic scenarios that occur when performing compliance by permit stage: modeling *future construction* features that are not included in the permit application, and modeling *existing construction* that has complied with the *Standards.*

Modeling Future Construction by Permit Stage

When a feature of a building is not included in the permit application, it is required to *default* to a feature automatically determined in the computer program. The defaults vary for envelope, mechanical, and lighting. The *ACM Approval Manual* contains additional information on the default values.

The *default envelope features* do not apply when modeling future construction. Usually, this is the first permit requested and at a minimum this feature must be modeled. The proposed building's envelope features are input and an energy budget is automatically generated based on the proposed building's envelope, and/or space conditioning and lighting system.

The *default space conditioning system* features are fixed if no space conditioning system exists in the building. A standard package gas/electric unit is assumed for each thermal zone in the proposed design. The package system is sized based on the envelope design and it meets the prescriptive requirements. If a space conditioning system is included in the permit application, the default space conditioning system is based on the standard design as determined in the *ACM Approval Manual*.

The *default service water heating system* features are fixed based on building occupancy. Default service water heating systems are specified for each occupancy type.

The *default lighting system* features depend on whether or not the occupancy of the building is known. If the building occupancy is known, the Allowed Lighting Power Density is determined using the Complete Building Approach for each zone that the occupancy is known. If the building occupancy is not known, 1.5 watts per square foot is assumed for both the proposed energy use and the energy budget.

Modeling Existing Construction by Permit Stage

When a feature of a building is not included in the permit application, and it is an existing building feature, it is required to *default* to a feature automatically determined in the computer program. The defaults vary for envelope, mechanical, and lighting. The *ACM Approval Manual* contains additional information on the default values.

The *default envelope* features are based on the program user's inputs to the computer program. The proposed building's conditioned floor area, glazing, wall, floor/soffit, roof/ceiling, and display perimeter features are input by the program user. The computer program then applies the proposed building's features to the standard design in order to calculate the energy budget. This means that if an application for an envelope permit is not being sought , the computer program will automatically default the features of the standard design to be the same as the features of the proposed design. Only the EXISTING-ENV will be printed to document the existing building.

The *default space conditioning system* features are fixed based on the building's existing space conditioning system. The program user inputs the existing space conditioning system, including actual sizes and types of equipment. The computer program then applies the proposed building's space conditioning features to the standard design in order to calculate the energy budget. This means that if an application is not being sought for a mechanical permit, the computer program will automatically default the features of the standard design to be the same as the features of the proposed design. No mechanical forms will be printed.

The *default service water heating system* features are fixed based on building occupancy. Default service water heating systems are specified for each occupancy type. Water heating information will only be listed as "existing".

The default lighting system features are based on the known occupancy of the building. The Allowed Lighting Power Density is determined based on the Actual Lighting Power Density of the building. The computer program then applies the proposed building's features to the standard design in order to calculate the energy budget. This means that if an application for a lighting permit is not being sought, the computer program will automatically default the features of the standard design to be the same as the features of the proposed design. No LTG form will be printed. All reported lighting will be reported on the PERF-1 Performance Certificate of Compliance.

Additions Performance Compliance

An addition is treated similar to a new building in the performance approach. Since both new conditioned floor area and volume are created with an addition, all systems serving the addition will require compliance to be demonstrated. This means that either the prescriptive or performance approach can be used for each stage of the addition's construction.

NOTE: When existing space conditioning or water heating is extended from the existing building to serve the addition, those systems do not need to comply.

Addition Only

Additions that show compliance with the performance approach, independent of the existing building, must meet the requirements for new buildings. *Standards* §149(a)2 states that the envelope and lighting of the addition, and any newly installed space conditioning or service water heating system serving the addition, must meet the mandatory measures and the energy budget determined in the performance run.

If the permit is done in stages, the rules for each permit stage apply to the addition performance run.

If the whole addition is included in the permit application, the rules for whole buildings apply.

Existing plus Addition

Additions may also show compliance by *either* 1) demonstrating that efficiency improvements to the existing building offset decreased addition performance (see §149(a)2.B.2.), or 2) that the existing building combined with the addition meets the present *Standards* (per §149(b). *Standards* §149(a)2 states that the envelope and lighting of the addition, and any newly installed space conditioning or service water heating system serving the addition, must meet the mandatory measures just as if it was an addition only. It also allows the applicant to improve the energy efficiency of the existing building so that it meets the energy budget that would apply to the entire building, if the existing building was unchanged, and the addition complied on its own.

It is important to note that the term entire building means the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all conditioned and unconditioned space within the structure.

To show compliance with this approach you need to follow the instructions in the computer program's compliance supplement.

When using this compliance approach it is important to take into account all changes in the building's features that are removed from or added to the existing building.

Documentation of the existing building's features is required to be submitted with the permit application if this method is used.

Alterations Performance Compliance

Using the performance approach for an alteration is similar to demonstrating compliance with an addition.

Alteration Only

Altered spaces can show compliance with the performance approach independent of the existing building, and must meet the requirements for new buildings. *Standards* §149(b)2 states that the envelope and lighting of the alteration, and any newly installed space conditioning or service water heating system serving the alteration, must meet the mandatory measures and the permitted space alone shall comply with the energy budget determined using an alternative computer program.

If the permit is done in stages, the rules for each permit stage apply to the alteration performance run.

Existing Buildings with Whole Building Approach Alteration

Alterations may also show compliance by demonstrating that efficiency improvements to the existing building offset decreased performance of the permitted space. *Standards* §149(a)2 states that envelope, lighting, space conditioning or service water heating system alterations, must meet the mandatory measures. This approach allows the applicant to improve the energy efficiency of the existing building so that it meets the energy budget that would apply to the entire building if the existing building was unchanged, and the permitted space complied on its own.

To show compliance with this approach you need to follow the instructions in the computer program's compliance supplement.

When using this compliance approach it is important to take into account all changes in the building's features that are removed from or added to the existing building as a part of the alteration.

Documentation of the existing buildings features is required to be submitted with the permit application if this method is used. An EXISTING-ENV report must be presented.

Alternate Performance Compliance Approach

Any addition, alteration or repair may demonstrate compliance by meeting the requirements applicable to new buildings for the entire building. Using this method, the entire building could be shown to comply in permit stages or as a whole building. The rules for new buildings, permit stage compliance, and whole building compliance would apply.

Documentation of the existing buildings features is required to be submitted with the permit application if this method is used.

F. Professional Judgment

As explained in the next section, certain modeling techniques and compliance assumptions applied to the proposed design are fixed or restricted. That is, there is little or no freedom to choose input values regarding specific input variables for compliance modeling purposes. However, there remain other aspects of computer modeling for which professional judgment is necessary. In those instances, it must be exercised properly in evaluating whether a given assumption is appropriate.

Building departments have full discretion to question the appropriateness of a particular input, especially if the user has not substantiated the value with supporting documentation.

Two questions may be asked in order to resolve whether good judgment has been applied in any particular case:

- Is the approach or assumption used in modeling the proposed design consistent with the approach or assumption used in generating the energy budget?

  The rule is to model the proposed design using the same assumption and/or technique used by the program in calculating the energy budget unless drawings and specifications indicate specific differences that warrant conservation credits or penalties.

- Is a simplifying assumption appropriate for a specific case?

  If simplification reduces the energy use of the proposed building when compared to a more explicit and detailed modeling assumption, the simplification is not acceptable.

6.1.3 Analysis Procedures

This section is a summary of the analysis procedures used in demonstrating compliance with approved computer programs. It describes the procedures specified in §141 of the *Standards. Program users and those checking for enforcement should consult the most current version of the user’s manuals and associated compliance supplements for specific instructions on the operation of the program*
.

Although there are numerous requirements for each ACM input, the data entered into each approved computer program may be organized differently from one program to the next. As a result, it is not possible in this summary to present all variables in their correct order or hierarchy for any one program. The aim is simply to identify the procedures used to calculate the standard design energy budget and the source energy use of the proposed building.

A. Energy Budget

The energy budget consists of three main components: the space conditioning energy budget, the lighting budget, and the service water heating budget. These components are discussed in §141(a)1, 2 and 3 of the *Standards.*

Space Conditioning Energy Budget

The space conditioning budget is defined in *Standards* §141(a)1 as "... the source energy used for space conditioning in a standard building in the Climate Zone in which the proposed building is located, calculated with a method approved by the Commission...." The space conditioning energy budget is automatically determined from the program user's inputs from the corresponding elements of the proposed design. This budget is automatically re-calculated each time a compliance run is done.

The space conditioning energy budget consists of the elements described in the *ACM Approval Manual*.

Lighting Energy Budget

The lighting energy budget is defined in the *Standards* §141(a)2 as "...the source energy used for lighting in a standard building calculated with a method approved by the Commission..." The budget consists of the lighting power used by a building based on one of the following criteria:

- When no lighting plans or specifications are submitted for permit, and the occupancy of the building is not known, the standard lighting power density is 1.2 watts per square foot.
- When no lighting plans or specifications are submitted for permit and the occupancy of the building is known, the *standard lighting power density* is equal to the corresponding watt per square foot value derived in the Complete Building Method (*Standards* §146(b)1).
- When lighting plans and specifications are submitted for permit, the standard and proposed lighting power density is equal to the corresponding total allowed lighting power (in watts) calculated using either the Complete Building Method, the Area Category Method, or the Tailored Method (*Standards* §146(b)1, 2 or 3). A complete set of lighting plans and prescriptive forms are required for use of the Tailored Lighting Method in the performance approach. The ACM calculated lighting power must always be within 2% of the lighting power calculated by the performance approach.

The *Standards* only allow lighting trade-offs against the allowed watts per square foot based on actual occupancy (general lighting categories A through D). Submitted lighting plans must show lighting loads equal to or less than on the energy documentation.

Service Water Heating Energy Budget

The service water heating energy budget is defined in the *Standards* §141(a)3 as "...the source energy used for service water heating in a standard building calculated in the Climate Zone in which the proposed building is located, calculated with a method approved by the Commission...." The budget consists of the service water heating energy used by a building assuming the service water heating system meets both the mandatory and prescriptive requirements as described in Section 4.2.1K and 4.2.2I of this *Manual* (*Standards* §111, §113 and §123).

B. Source Energy Use

The source energy use consists of three main components; the space conditioning energy use, the lighting energy use, and the service water heating energy use. These components are discussed in §141(b)1, 2, and 3 of the *Standards.*

The key component of calculating the source energy use of the proposed building is that if a feature of the building is not included in the building permit application, the energy use of that feature is equal to that of the standard energy budget (*Standards* §141(b)). That means that if a permit is submitted for a shell building (envelope only), and the performance approach is used to demonstrate compliance, trade-offs cannot be made between the envelope and the mechanical or lighting system.

Space Conditioning Source Energy Use

The space conditioning source energy use must be calculated using a method approved by the Energy Commission. The following elements are used by the approved computer programs. These elements must be consistent with plans and specifications submitted in the building permit application:

Gross Exterior Surfaces: All gross exterior surfaces, each with its respective area, orientation and tilt.

Opaque Exterior Walls: Each opaque exterior wall construction assembly, as well as wall area, orientation and tilt. Heat capacities, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior walls, must be included.

Doors: All doors must be included.
Opaque Roofs/Ceilings: Each opaque exterior roof/ceiling construction assembly, as well as roof/ceiling area, orientation and tilt. Heat capacity, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior roof/ceilings, must be included.
Raised Floors and Slab Floors: Each floor construction assembly, as well as floor area.

Glass in Walls and Shading: Each vertical glass area, orientation, tilt, U-value and shading coefficient.

Horizontal (Skylight) Glass and Shading: Each horizontal or skylight glass area, orientation, tilt, U-value and shading coefficient.

Ventilation (Outside) Air: Ventilation (or outside air) values in cfm/sf.

Fan Power: Fan power must be included.

Cooling and Heating Efficiency: The actual efficiency of the equipment included in the proposed design.

No Heating or Cooling Installed: If total heating or cooling capacity is not specified, the source energy use will be based on a standard design heating or cooling system (*Standards* §141(b)).

Cooling System Capacity: Sensible output capacity of the cooling system at ARI conditions.
Heating System Capacity: The output capacity of the heating system.

Other System Values: All other space conditioning system components that are used by approved computer programs.

Refer to the *ACM Approval Manual* for more detailed information on how each of the above values are used by the computer programs.

Lighting Source Energy Use

The lighting source energy use is calculated using a method approved by the Energy Commission. When plans and specifications are submitted for permit, the lighting source energy use is calculated using the following elements:

Proposed Lighting Power Density: For all occupancies except Hotel Guest Rooms and High-rise residential living quarters, the proposed lighting power density, in watts per square foot (*Standards* §141(a)2).

For residential occupancies (Hotel Guest Rooms or High-rise Residential Buildings), the approved computer program will always fix the proposed lighting power density at the values listed in the *ACM Approval Manual.*

Service Water Heating Source Energy Use

The service water heating source energy use is calculated using a method approved by the Energy Commission. It is calculated using a method described in the *ACM Approval Manual* using the proposed building service water heating system. This system must be consistent with plans and specifications submitted in the building permit application

6.1.4 Performance Plan Check Documents

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the forms and procedures for documenting compliance with the performance requirements of the *Standards* when an Alternative Calculation Method (ACM), typically a computer program, is used to demonstrate compliance. The *ACM Approval Manual* has specific and detailed output/reporting requirements for all approved ACMs. The administrative regulations require certain specific forms and only those forms for a particular type of compliance by referencing the *ACM Approval Manual* requirements.

ACM compliance output is required to specify the run initiation time, a unique runcode, and the total number of pages of forms printed for each proposed building run whenever a building complies with the *Standards* and compliance output has been selected. The plan checker is strongly encouraged to verify these output features for a performance compliance submittal to ensure that the submittal is a consistent set of compliance documentation. The *ACM Approval Manual* forbids an ACM from printing standard compliance forms for a proposed building design that does not comply. The plan checker should pay special attention to the PERF-1 form and the Exceptional Conditions List on Part 2 of that form. Every item on the Exceptional Conditions List deserves special attention and requires additional documentation such as manufacturer's cut sheets or special features on the plans and in the building specifications.

The ACM requirements will automatically produce and reiterate the proper set of forms that correspond to the particular proposed building submitted for a permit, but the plan checker should verify the type of compliance and the required forms from the lists below. Whenever an existing building (or building components) is involved in compliance, the plan checker should look for an EXISTING form that documents EXISTING building components. Similarly if the compliance indicates existing components - partial permit compliance, addition, addition plus existing building, or any alteration, an EXISTING form must be submitted. In the types of permit applications where some building components are unknown the unknown components cannot be entered by the user and cannot be reported on output forms.

This section does not describe the details of the performance approach; these are reviewed in Section 6.1.1 and 2, in the computer program vendors' compliance supplements, and in the *ACM Approval Manual*. The following discussion is addressed primarily to the building department plan checkers who are examining documents submitted to demonstrate compliance with the *Standards*, and to the designer preparing construction documents and compliance documentation.

Most compliance forms associated with the computer method approach are generated automatically. These reports are similar in information content and layout to their prescriptive method counterparts. The main difference is appearance because computer method forms are designed to be reproducible using a dot matrix printer.

The following summary identifies the forms that are required for performance compliance. All submittals must contain the following information:

- Unless minimal efficiency and default capacities are used in the performance analysis, either equipment cut sheets showing rated capacities, fan bhp, and air flow at ARI conditions, or the installation certificate must be provided.

- Other documentation supporting each non-standard or non-default value used in the performance approach and indicated in the Exceptional Conditions list on the PERF-1 form must also be included.

Other reports that may be generated by a program are:

- ENV-3: Construction Assemblies

- Formatted Copy of Input

The following computer generated forms are required by the *ACM Approval Manual* for a permit application:

Whole Building Compliance (the number of parts is the minimum number of pages)

- PERF-1: Performance Certificate of Compliance (3 parts)

- ENV-1: Envelope Compliance Summary (1 part)

- MECH-1: Mechanical Compliance Summary (2 parts)

- MECH-2: Mechanical Equipment Summary (2 parts)

- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation (1 part)

- LTG-1: Lighting Compliance Summary (1 part)

The LTG-3 (Lighting Controls Credit Worksheet) and LTG-4 (Tailored LPD Summary and Worksheet) forms may be, and typically will be, submitted by hand. When these pages are hand submitted or submitted independently, they will not be included in the page count automatically generated by the computer for a compliance submittal. NOTE: the use of the tailored lighting approach requires independent prescriptive compliance for the lighting system.

Compliance By Permit Stage (the number of form parts are the same as indicated above at Whole Building Compliance)

Envelope Only

- PERF-1: Performance Certificate of Compliance
- ENV-1: Envelope Compliance Summary
- ENV-3: Construction Assemblies
- Possibly existing LTG and existing MECH forms: (for partial compliance alteration)

Envelope and Mechanical

- PERF-1: Performance Certificate of Compliance
- ENV-1: Envelope Compliance Summary
- MECH-1: Mechanical Compliance Summary
- MECH-2: Mechanical Equipment Summary
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation
- Possibly existing LTG forms: (for partial compliance alteration)

Mechanical Only

- PERF-1: Performance Certificate of Compliance
- MECH-1: Mechanical Compliance Summary
- MECH-2: Mechanical Equipment Summary
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation
- Possibly existing ENV and/or existing LTG forms: (for partial compliance alteration)

Mechanical and Lighting

- PERF-1: Performance Certificate of Compliance
- MECH-1: Mechanical Compliance Summary
- MECH-2: Mechanical Equipment Summary
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation
- LTG-1: Lighting Compliance Summary
- LTG-3: Lighting Controls Credit Worksheet (if control credits used)
- LTG-4: Tailored LPD Summary and Worksheet (if tailored lighting used)
- Possibly existing ENV forms: (for partial compliance alteration)

Lighting Only

- PERF-1: Performance Certificate of Compliance
- LTG-1: Lighting Compliance Summary
- LTG-3: Lighting Controls Credit Worksheet (if control credits used)
- LTG-4: Tailored LPD Summary and Worksheet (if tailored lighting used)
- Possibly existing ENV and existing MECH forms: (for partial compliance alteration)

Consult the computer program's compliance supplement for a detailed summary of what additional documentation may need to be included in the permit application along with the automatically-generated compliance documentation.

A. PERF-1: Performance Certificate of Compliance

The PERF-1 incorporates the first parts of the prescriptive ENV-1, LTG-1, and MECH-1 on the first part or first page. This is a combined signature document for the certificate of compliance that documents the party(ies) who has primary responsibility for the design of the envelope, lighting and mechanical systems of the building. The total Btu/sf/yr for the standard design energy budget must be equal to or greater than the proposed design's energy use.

The signature statement is to certify that the documentation author correctly represented the building in the performance program.

The PERF-1 form must appear on the plans (usually near the front of the architectural drawings). A copy of this form should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. This form must be generated by an approved alternative computer program.

B. ENV-1: Envelope Compliance Summary

The performance ENV-1 Envelope Compliance Summary form has one part. It summarizes the opaque surfaces including surface type, construction type, area, azimuth, and U-value . Next it summarizes the fenestration surfaces including fenestration type, area, azimuth, U-value, frame type and solar heat gain coefficient. Lastly, it includes exterior shading and overhangs including shade type, solar heat gain coefficient, overhang height and overhang width.

For a description of the information contained on the ENV-1 Envelope Compliance Summary, see ENV-1, Part 2 of 2, Section 3.3.1.

C. ENV-3: Construction Assemblies

This form is identical to the form required in the prescriptive approach and is described in Section 3.3.4 through 3.3.6.

D. EXISTING-ENV: Performance Method

The ENV-E Performance Method form is used to identify a space. The intention of this form is to be used only in cases where the envelope has complied previously and compliance is now being sought for lighting, mechanical or both. The form includes address, date envelope complied, space name, occupancy, floor area, and volume. The form also identifies opaque surface areas and U-values as well as glazing surface areas, U-values, and shading coefficients.

E. MECH-1: Mechanical Compliance Summary

The MECH-1 Mechanical Compliance Summary form is in two parts. This form identifies the system features, duct insulation and pipe insulation that will be verified by the field inspector.

For a description of the information contained on the MECH-1 Mechanical Compliance Summary, see Section 4.3.1 and consult the computer program's compliance supplement.

F. MECH-2: Mechanical Equipment Summary

The MECH-2 Mechanical Equipment Summary identifies the mechanical equipment modeled in the alternative computer program to show compliance. The form contains the information of the equipment name, type, number of pieces, efficiency and size, and is broken down by plant equipment (chillers, boilers, VAV, etc.) and exhaust fans.

For more information on the MECH-2, refer to computer program's compliance supplement.

G. MECH-3: Mechanical Compliance Summary/Mechanical Ventilation

The MECH-3 Mechanical Compliance Summary/Mechanical Ventilation contains the information on the design outdoor ventilation rate for each space. Refer to the discussion in Section 4.3.4, and the computer program's compliance supplement for more information.

H. LTG-1: Lighting Compliance Summary

The LTG-1 Lighting Compliance Summary form is a single part form. It is used to describe the lighting fixtures and control devices designed to be installed in the building.

For a description of the information contained on the LTG-1 Lighting Compliance Summary, see LTG-1, Part 2 in Section 5.3.1.

If control credits were input by the program user, a copy of the LTG-3 must accompany the permit application. If the Tailored LPD was used, a copy of the LTG-4 must accompany the permit application along with a complete set of lighting plans and specifications.

6.1.5 Performance Inspection

Performance approach inspection is identical to other inspections required by the *Standards.* For information on inspection envelope, mechanical and lighting systems, see Sections 3.4, 4.4 and 5.4, respectively.

When tailored lighting is used to justify increases in the lighting load, a lower lighting load cannot be modeled for credit. The standard design building uses the lesser of allowed watts per square foot or actual lighting power to be installed in the building. The proposed design building uses the actual lighting power to be installed as detailed on the lighting plans. This value must be equal to or greater than the allowed watts per square foot.

6.2 HOTELS AND MOTELS

6.2.1 Introduction

This section discusses the requirements of the *Standards* as they apply to hotels and motels. It addresses both the similarities and differences between showing compliance for a hotel/ motel and any other nonresidential or high-rise residential building. Additional information is presented regarding documenting special situations in hotel/motel compliance, and plan checking.

The design of a hotel or motel is unique in that the design must incorporate a wide variety of occupancies and functions into one structure. The occupancies range from nonresidential occupancies to hotel/motel guest rooms. Design functions that affect guests range from the "experience of arrival" created through the main lobby's architectural features to the thermal comfort of the guest rooms. Other functions that hotel/motel designs must address include restaurants, kitchens, laundry, storage, light assembly, and other items that are necessary to the hotel/motel function. In short, these structures can range from simple guest rooms with a small office, to a structure encompassing a small city.

The following sections discuss how they comply with the *Standards*.

6.2.2 Hotel/Motel Compliance Approaches

The *Standards* treat hotels/motels similarly to other occupancies: compliance is submitted for the features covered in the permit application only. Occupancy type is considered in two cases: Nonresidential portions of hotel/motels and guest room portions of hotels/motels. The nonresidential areas of hotels/motels must meet the envelope, mechanical, and lighting portions of the *Energy Efficiency Standard for Nonresidential Buildings*, and the guest room portions of hotels/motels must meet the envelope, mechanical and lighting provisions applicable only to hotels/motel guest rooms. In essence, each occupancy individually complies with the provisions applicable to that occupancy.

6.2.3 Basic Hotel/Motel Concepts

Since hotel/motels are treated as a mixture of occupancies covered by the *Standards,* the concepts presented at the beginning of each chapter apply equally to hotels/motels as they would any other nonresidential occupancy. Special cases where hotels/motel concepts are discussed include the following:

- Section 2.1.2B discusses occupancies that are covered by the *Standards.* This includes the definition of hotels/motels and a discussion of how to determine whether a building is a hotel/motel, high-rise residential, or low-rise residential.
- Section 5.1.2B includes a list of occupancy types that may be used to determine the lighting power density. The full definitions of these occupancies are included in Appendix G.

6.2.4 Hotel/Motel Compliance

The following subsections discuss the special compliance requirements that apply to hotel/motel occupancies.

A. Mandatory Measures

The mandatory measures for envelope, mechanical and lighting, as described in Sections 3.2.1, 4.2.1 and 5.2.1, apply to hotels/motels.

In addition, a special requirement applies to the lighting in hotel/motel guest rooms. This requirement states that 90 percent of the hotel/motel guest rooms must meet bathroom and kitchen lighting requirements, if any, that apply to low-rise residential buildings. An explanation of this requirement is included in Appendix H.

EXCEPTIONS

The following exceptions to mandatory measures are specific to hotel/motels:

Envelope

- Manufactured fenestration products installed in hotel/motel guest rooms must be certified as meeting the nonresidential values for both air infiltration and fenestration U-value. If default U-values are used, they shall be consistent with the default values contained in Section 3.1.2H. If an NFRC certified fenestration product is used, the U-value for commercial size categories shall be used.

Mechanical

- Hotel and motel guest room thermostats shall have numeric temperature settings. Section 4.2.1H contains an explanation of these requirements.
- Process loads in hotels and motels are discussed in Section 4.2.1H. Process loads in hotels/motels are treated similar to any other nonresidential building.

Lighting

- Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.
- Automatic shut-off controls are not required for hotel/motel guest rooms.

B. Prescriptive Compliance

The prescriptive requirements for envelope, mechanical and lighting, as described in Sections 3.2.2, 4.2.2 and 5.2.2, apply to hotel/motels.

The following prescriptive requirements are specific to hotel/motels:

Envelope

- Special requirements apply to the envelope in hotel/motel guest rooms. These requirements state that the envelope must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings. An explanation of this requirement is included in Section 3.2.2.

Mechanical

- Hotel and motel guest rooms are not required to have economizer controls. Section 4.2.2F contains an explanation of these requirements.

Lighting

- Guest rooms in hotel/motels are exempt from the lighting power density requirements. Section 5.2.4. contains a discussion of exempt lighting.
- Each occupancy (other than guest rooms) in the hotel/motel must comply with either the Area Category Method or the Tailored Method. The Complete Building Method may not be used. These methods cannot be mixed within a permit application. See Section 5.2.2 for a more complete discussion of how to use these compliance approaches.

C. Performance Compliance

The rules for performance compliance are identical to the rules for complying all other nonresidential and high-rise residential buildings. The area of each function of a hotel/motel is input into the program along with its corresponding envelope, mechanical and lighting features. The computer program will automatically calculate an energy budget for the standard design, and the proposed design's energy use.

A complete discussion of the performance approach is included in Section 6.1.

6.2.5 Hotel/Motel Plan Check Documents

Documenting compliance with the S*tandards* is similar to complying other nonresidential or high-rise residential buildings. The forms, and instructions for completing the forms, are included in Sections 3.3, 4.3, 5.3 and 6.1 of this manual. Exempt lighting, including guest room lighting, does not have to be listed on the LTG-1, or LTG-4 tailored forms, but should be clearly identified on the plans.

6.2.6 Hotel/Motel Inspection

Inspecting for compliance with the *Standards* is similar to complying other nonresidential or high-rise residential buildings. The field inspection checklist and inspection instructions are included in Sections 3.4, 4.4, 5.4 and Appendix I of this manual.

6.3 HIGH-RISE RESIDENTIAL

6.3.1 Introduction

This section discusses the requirements of the *Standards* as they apply to high-rise residential buildings. It addresses both the similarities and differences between showing compliance for a high-rise residential building and any other nonresidential building. Additional information is presented regarding documenting special situations in high-rise residential compliance, plan checking, and field inspection.

The design of a high-rise residential building must incorporate the structural and mechanical elements of a nonresidential building, with the lighting and service hot water needs of residential buildings. The *Standards* address these features of high-rise residential buildings as described below.

6.3.2 High-rise Residential Compliance Approaches

The *Standards* treat high-rise residential buildings similar to any other occupancy: compliance is submitted for the features covered in the permit application only. Occupancy type is considered in two cases: Portions of high-rise residential buildings that are considered living quarters, and all other portions of the building. Living quarters are those non-public portions of the building in which a resident lives. The nonresidential areas of high-rise residential buildings are all other areas.

The nonresidential areas must meet the lighting portions of the *Energy Efficiency Standard for Nonresidential Buildings*, and the living quarters must meet the lighting and service water heating provisions applicable only to high-rise residential living quarters.

6.3.3 Basic High-rise Residential Concepts

The concepts presented at the beginning of each chapter apply equally to high-rise residences as they would any other nonresidential occupancy. Special cases where high-rise residence concepts are discussed include the following:

- Section 2.1.2B discusses occupancies that are covered by the *Standards*. This includes the definition of high-rise residential and a discussion of how to determine whether a building is a high-rise residence, or low-rise residence.
- Section 5.1.2C. includes a list of occupancy types that may be used to determine the lighting power density. The full definitions of these occupancies are included in Appendix G.

6.3.4 High-rise Residential Compliance

The following subsections discuss the special compliance requirements that apply to high-rise residential occupancies.

A. Mandatory Measures

The mandatory measures for envelope, mechanical and lighting, as described in Sections 3.2.1, 4.2.1 and 5.2.1, apply to high-rise residential buildings.

In addition, a special requirement applies to the lighting in high-rise residential living quarters. This requirement states that the living quarters must meet bathroom and kitchen lighting requirements that apply to low-rise residential buildings. An explanation of this requirement is included in Appendix H.

The following exceptions to mandatory measures are specific to high-rise residential buildings:

Envelope

- Manufactured fenestration products installed in high-rise residential buildings must be certified as meeting the nonresidential values for both air infiltration and fenestration U-value. If default U-values are used, they shall be consistent with the default values contained in Section 3.1.2H. If an NFRC certified fenestration product is used, the U-value for commercial size categories shall be used.

Mechanical

- High-rise residential occupancies must meet setback requirements applicable to low-rise residential occupancies.

Lighting

- Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.

- Automatic shut-off controls are not required for living quarters.

B. Prescriptive Compliance

The prescriptive requirements for envelope, mechanical and lighting, as described in Sections 3.2.2, 4.2.2 and 5.2.2, apply to high-rise residences.

The following prescriptive requirements are specific to high-rise residences:

Envelope

- Special requirements apply to the envelope in high-rise residential buildings. These requirements state that the envelope must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings. An explanation of this requirement is included in Section 3.2.2.

Mechanical

- High-rise residential living quarters are not required to have economizer controls. Section 4.2.2F contains an explanation of these requirements.

Lighting

- High-rise residential living quarters are exempt from the lighting power density requirements. Section 5.2.4 contains a discussion on exempt lighting.

- Each occupancy (other than living quarters) in the high-rise residence must comply with either the Area Category Method or the Tailored Method. These methods cannot be mixed within a permit application. See Section 5.2.2 for a more complete discussion of how to use these compliance approaches.

C. Performance Compliance

The rules for high-rise residential performance compliance are identical to the performance compliance rules for all nonresidential buildings. The area of each function of a high-rise residence is input into the program along with its corresponding envelope, mechanical and lighting features. The computer program will automatically calculate an energy budget for the standard design, and the proposed design's energy use.

A complete discussion of the performance approach is included in Section 6.1.

6.3.5 High-rise Residential Plan Check Documents

Documenting high-rise residential compliance with the *Standards* is similar to documenting compliance for other nonresidential buildings. The forms, and instructions for completing the forms, are included in Sections 3.3, 4.3, 5.3, 6.1 and Appendix H of this manual.

6.3.6 High-rise Residential Inspection

Inspecting high-rise residential for compliance with the *Standards* is similar to inspecting for compliance with other nonresidential buildings. The field inspection checklist and inspection instructions can be found in Appendix I of this manual.

6.4 SAMPLE PERFORMANCE FORMS

The following pages are sample performance forms.

PERFORMANCE CERTIFICATE OF COMPLIANCE (Part 1 of 3) PERF-1

PROJECT NAME		DATE
PROJECT ADDRESS		Building Permit #
PRINCIPAL DESIGNER-ENVELOPE	TELEPHONE	Checked by/Date
DOCUMENTATION AUTHOR	TELEPHONE	Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA	CLIMATE ZONE

BUILDING TYPE ☐ NONRESIDENTIAL ☐ HIGH RISE RESIDENTIAL ☐ HOTEL/MOTEL GUEST

PHASE OF CONSTRUCTION ☐ NEW CONSTRUCTION ☐ ADDITION ☐ ALTERATION ☐ EXISTING + ADDITION

STATEMENT OF COMPLIANCE

This Certificate of Compliance lists the building features and performance specifications needed to comply with Title 24, Parts 1 and 6 of the State Building Code. This certificate applies only to a building using the performance compliance approach.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Designers hereby certify that the proposed building design represented in the construction documents and modeled for this permit application are consistent with all other forms and worksheets, specifications, and other calculations submitted with this permit application. The proposed building as designed meets the energy efficiency requirements of the State Building Code, Title 24, Part 6.

ENV. LTG. MECH.

☐ ☐ ☐ 1. I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for its preparation; and that I am licensed in the State of California as a civil engineer, mechanical engineer (envelope & mechanical only), or electrical engineer (lighting only) or I am a licensed architect.

☐ ☐ ☐ 2. I affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code Section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ ☐ ☐ 3. I affirm that I am eligible under Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described as exempt pursuant to Business and Professions Code Sections 5537, 5538 and 6737.1. (These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

ENVELOPE COMPLIANCE

Indicate location on plans of Note Block for Mandatory Measures:

Required Forms: TELEPHONE

LICENSED ENGINEER/ARCHITECT/CONTRACTOR – NAME	SIGNATURE	LIC. NO.	DATE

LIGHTING COMPLIANCE

Indicate location on plans of Note Block for Mandatory Measures:

Required Forms: TELEPHONE

LICENSED ENGINEER/ARCHITECT/CONTRACTOR – NAME	SIGNATURE	LIC. NO.	DATE

MECHANICAL COMPLIANCE

Indicate location on plans of Note Block for Mandatory Measures:

Required Forms: TELEPHONE

LICENSED ENGINEER/ARCHITECT/CONTRACTOR – NAME	SIGNATURE	LIC. NO.	DATE

Run Initiation Time: **Run Code:**

PERFORMANCE CERTIFICATE OF COMPLIANCE (Part 2 of 3) PERF-1

PROJECT NAME	DATE

ANNUAL SOURCE ENERGY USE SUMMARY (kBtu/sqft-yr)

ENERGY COMPONENT	Standard Design	Proposed Design	Compliance Margin
Space Heating			
Space Cooling			
Indoor Fans			
Heat Rejection			
Pumps			
Domestic Hot Water			
Lighting			
Receptacle			
Process			
TOTALS:			

BUILDING COMPLIES

GENERAL INFORMATION

Building Orientation		Conditioned Floor Area	
Number of Stories		Unconditioned Floor Area	
Number of Systems			
Number of Zones			

	Orientation	Gross Area		Glazing Area		Glazing Ratio
Front Elevation			sqft		sqft	
Left Elevation			sqft		sqft	
Rear Elevation			sqft		sqft	
Right Elevation			sqft		sqft	
Total			sqft		sqft	
Roof			sqft		sqft	

	Standard		Proposed	
Lighting Power Density		W/sqft		W/sqft
Perscriptive Env. Heat Loss				
Perscriptive Env. Heat Gain				

Run Initiation Time: **Run Code:**

PERFORMANCE CERTIFICATE OF COMPLIANCE (Part 3 of 3) PERF-1

PROJECT NAME	DATE

ZONE INFORMATION

System Name	Zone Name	Occupancy Type	Floor Area (sqft.)	Installed LPD (W/sf)[1]	Control Credits (W/sf)[1]	Tailored		Process Loads (W/sf)[3]
						LPD (W/sf)[2]	Vent. (cfm/sf)[3]	

Notes: 1. See LTG-1 **2.** Provide Tailored Lighting Forms & Lighting Plans for Tailored LPD **3.** Provide Supporting Documentation

EXCEPTIONAL CONDITIONS COMPLIANCE CHECKLIST

The local enforcement agency should pay special attention to this checklist. These items require special written justification and documentation, and special verification to be used with the performance approach. The local enforcement agency determines the adequacy of the justification, and may reject a building or design that otherwise complies based on the adequacy of the special justification and documentation submitted.

	PLAN	FIELD

The exceptional features listed in this performance approach application have specifically been reviewed. Adequate written justification and documentation for their use have been provided by the applicant.

Authorized Signature or Stamp____

Run Initiation Time: **Run Code:**

ENVELOPE COMPLIANCE SUMMARY Performance ENV-1

PROJECT NAME	DATE

OPAQUE SURFACES

#	Surface Type	Construction Type (e.g., Block, Wood, Metal)	Area	U-ValUE	Azimuth	Tilt	Solar Gains Y/N	Form 3 Reference	Location / Comments (e.g., Suspended Ceiling, Demising, etc.)
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		
							☐ ☐		

FENESTRATION SURFACES

#	Fenestration Type	Area	U-Value	Azimuth	SHGC	Glazing Type	Location / Comments

EXTERIOR SHADING

Fenestration #	Exterior Shade Type	SHGC	Window		Overhang				Left Fin			Right Fin		
			Height	Width	Length	Height	LExt.	RExt.	Dist.	Length	Height	Dist.	Length	Height

Run Initiation Time: **Run Code:**

LIGHTING COMPLIANCE SUMMARY Performance LTG-1

PROJECT NAME	DATE

INSTALLED LIGHTING SCHEDULE

		LAMPS			BALLASTS		Luminaire (Lamp + Ballast)		
Code	LUMINAIRE DESCRIPTION	Type DESCRIPTION	#	Watts Per Lamp	Type DESCRIPTION	#	#	Watts	TOTAL WATTS

SUBTOTAL FROM THIS PAGE	
BUILDING TOTAL	
LESS CONTROL CREDIT WATTS (From LTG-3)	
ADJUSTED ACTUAL WATTS	

MANDATORY AUTOMATIC CONTROLS

CONTROL LOCATION (Room #)	CONTROL IDENTIFICATION	CONTROL TYPE (Auto Time Switch, Exterior, etc.)	SPACE CONTROLED	NOTE TO FIELD

CONTROLS FOR CREDIT

CONTROL LOCATION (Room # or Dwg. #)	CONTROL IDENTIFICATION	CONTROL TYPE (Occupant, Daylight, Dimming, etc.)	LUMINAIRES CONTROLLED		NOTE TO FIELD
			TYPE	# OF LUMINAIRES	

NOTES TO FIELD - For Building Department Use Only

Run Initiation Time: **Run Code:**

MECHANICAL COMPLIANCE SUMMARY Performance MECH-1

PROJECT NAME	DATE

SYSTEM FEATURES

SYSTEM NAME		MECHANICAL SYSTEMS					NOTE TO FIELD
TIME CONTROL							
SETBACK CONTROL							
ISOLATION ZONES							
HEAT PUMP THERMOSTAT?							
ELECTRIC HEAT?							
FAN CONTROL							
VAV MINIMUM POSITION CONTROL?							
SIMULTANEOUS HEAT/COOL?							
HEATING SUPPLY RESET?							
COOLING SUPPLY RESET?							
VENTILATION							
OUTDOOR DAMPER CONTROL?							
ECONOMIZER TYPE							
DESIGN O.A. CFM (MECH-3, COLUMN H)							
HEATING EQUIPMENT TYPE							
HEATING EQUIPMENT EFFICIENCY							
COOLING EQUIPMENT TYPE							
COOLING EQUIPMENT EFFICIENCY							
MAKE AND MODEL NUMBER							
HEATING DUCT LOCATION	R-VALUE						
COOLING DUCT LOCATION	R-VALUE						
DUCT TAPE ALLOWED?							
PIPE TYPE (SUPPLY, RETURN, ETC…)							
PIPE INSULATION REQUIRED?							

CODE TABLES: Enter code from table below into columns above.

HEAT PUMP THERMOSTAT?	Y: Yes N: No
ELECTRIC HEAT?	
VAV MINIMUM POSITION CONTROL?	
SIMULTANEOUS HEAT/COOL?	
HEAT AND COOL SUPPLY RESET?	
HIGH EFFICIENCY?	
DUCT TAPE ALLOWED?	
PIPE INSULATION REQUIRED?	

TIME CONTROL	SETBACK CTRL.	ISOLATION ZONES	FAN CONTROL
S: Prog. Switch O: Occupancy Sensor M: Manual Timer	H: Heating C: Cooling B: Both	Enter number of Isolation Zones	I: Inlet Vanes P: Variable Pitch V: VFD O: Other C: Curve

VENTILATION	OUTDOOR DAMPER	ECONOMIZER	DESIGN O.A. CFM
B: Air Balance C: Outside Air Cert. M: Out. Air Measure D: Demand Control N: Natural	A: Auto G: Gravity	A: Air W: Water N: Not Required	Enter Design Outdoor Air CFM. Note: This shall be no less than Column H on MECH-3.

NOTES TO FIELD - For Building Department Use Only

Run Initiation Time: **Run Code:**

MECHANICAL EQUIPMENT SUMMARY Performance (Part 1 of 2) MECH-2

PROJECT NAME	DATE

CHILLER AND TOWER SUMMARY

Equipment Name	Equipment Type	Qty.	Efficiency	Tons	PUMPS Total Qty.	GPM	BHP	Motor Eff.	Drive Eff.	Pump Control

DHW / BOILER SUMMARY

System Name	System Type	Distribution Type	Qty.	Rated Input	Vol. (Gals.)	Energy Factor or Recovery Efficiency	Standby Loss or Pilot	TANK INSUL. Ext. R-Val

CENTRAL SYSTEM RATINGS

System Name	System Type	Qty.	HEATING			COOLING			
			Output	Aux. kW	Efficiency	Output	Sensible	Efficiency	Economizer type

CENTRAL FAN SUMMARY

System Name	Fan Type	Motor Location	SUPPLY FAN				RETURN FAN			
			CFM	BHP	Motor Eff.	Drive Eff.	CFM	BHP	Motor Eff.	Drive Eff.

Run Initiation Time: **Run Code:**

MECHANICAL EQUIPMENT SUMMARY Performance (Part 2 of 2) MECH-2

PROJECT NAME	DATE

VAV SUMMARY

	VAV					FAN					BASEBOARD	
Zone Name	System Type	Qty.	Min. CFM Ratio	Reheat? Type	Reheat? ΔT	Flow Ratio	CFM	BHP	Motor Eff.	Drive Eff.	Type	Output

EXHAUST FAN SUMMARY

EXHAUST FAN						EXHAUST FAN					
Room Name	Qty.	CFM	BHP	Motor Eff.	Drive Eff.	Room Name	Qty.	CFM	BHP	Motor Eff.	Drive Eff.

Run Initiation Time: **Run Code:**

MECHANICAL VENTILATION Performance MECH-3

PROJECT NAME	DATE

MECHANICAL VENTILATION

A	B	C	D	E	F	G	H	I	J	K
	AREA BASIS			OCCUPANCY BASIS						
ZONE/SYSTEM	COND AREA (SF)	CFM PER SF	MIN. CFM (B X C)	NO. OF PEOPLE	CFM PER PERSON	MIN. CFM (E X F)	REQ'D. O.A. (MAX. OF D OR G)	DESIGN OUTDOOR AIR CFM	VAV MIN. CFM	TRANFER AIR CFM

C Minimum ventilation rate per Section § 121, Table 1-F.

E Based on expected number of occupants or at least 50% of Chapter 10 1997 UBC occupant density

I Must be greater than or equal to H, or use Transfer Air. Design outdoor air includes ventilation from supply air system & exhaust fans which operate at design conditions.

K Must be greater than or equal to (H - I), and, for VAV, greater than or equal to (H - J).

Run Initiation Time: **Run Code:**

CHAPTER 6 INDEX

A

Actual Lighting Power · 6
Addition · 7
Allowed Lighting · 6
Allowed Lighting Power · 6
Allowed Lighting Power Density · 6
Alterations · 7
Alternative Calculation Method (ACM) · 2, 10
Alternative Calculation Methods Approval Manual · 3
Analysis Procedures · 1, 8
Application · 1, 5
Application Scenarios · 1, 5
Area · 3, 9, 15, 17
Area Category Method · 9, 15, 17
ARI · 10, 11

B

Building · 2, 3, 7, 8, 9, 15

C

California Code of Regulations · 3
California Code of Regulations, · 3
Certificate of Compliance · 1, 3, 7, 11, 12
Climate · 3, 9
Climate Zone · 9
Complete Building Approach · 6
Compliance · 1, 4, 5, 7, 8, 11, 12, 13, 14, 15, 17
Compliance by Permit Stage · 5
Compliance Procedure · 1, 5
Computer · 1, 2, 4
Computer Method · 1, 4
Computer Programs · 2
Concepts · 1, 2, 14, 16
Cooling · 10
Cooling System · 10
Cooling System Capacity · 10

D

Density · 6
Documentation · 7, 8
Doors · 10

E

Energy Budget · 1, 3, 8, 9
ENV-1 · 1, 11, 12, 13
ENV-3 · 1, 5, 11, 12, 13
Envelope Compliance · 11, 12, 13
Exceptional Conditions List · 11
Existing Buildings · 7
Existing Construction · 6
EXISTING-ENV · 1, 6, 8, 13
Exterior Walls · 10

F

Fan Power · 10
Future Construction · 6

G

Gross Exterior Surface · 10
Guest Room · 10

H

Heating · 10
Heating Efficiency · 10
Heating System Capacity · 10
Hotel/Motel · 1, 2, 3, 14, 16

I

Inspection · 1, 14, 16, 18

L

Lighting · 1, 9, 10, 11, 12, 13, 15, 17
Lighting Compliance Summary · 11, 12, 13
Lighting Controls · 11, 12
Lighting Controls Credit Worksheet · 11, 12
Lighting Energy Budget · 9
LTG-1 · 1, 11, 12, 13, 16
LTG-3 · 11, 12, 13
LTG-4 · 11, 12, 13, 16

M

Mandatory Measures · 1, 14, 16

MECH-1 · 1, 11, 12, 13
MECH-2 · 1, 11, 12, 13
MECH-3 · 1, 11, 12, 13
Mechanical Equipment · 11, 12, 13
Mechanical Equipment Summary · 12, 13
Mechanical Ventilation · 1, 11, 12, 13
Modeling · 6

N

No Heating or Cooling · 10

O

Occupancy · 3, 14, 16
Opaque · 10
Opaque Roofs/Ceilings · 10

P

Performance Approach · 1
Performance Plan Check · 1, 10
Permit · 6, 11
Plan Check Documents · 16, 17
Process · 15
Professional Judgment · 1, 8
Proposed Design · 3, 4
Proposed Lighting Power Density · 10

R

Raised Floors · 10
Residential Compliance · 16

S

Service Water Heating · 9, 10
Skylight · 10
Slab Floors · 10
Source Energy Use · 1, 3, 4, 9, 10
Space Conditioning · 9
Standard Design · 3, 4

T

Tailored LPD Summary and Worksheet · 12
Tailored Method · 9, 15, 17
Trade-offs · 4

U

U-value · 10, 13, 15, 17

V

Ventilation · 10

W

Whole Building Compliance · 5, 11

A: Compliance Forms

CERTIFICATE OF COMPLIANCE (Part 1 of 2) ENV-1

PROJECT NAME		DATE
PROJECT ADDRESS		
PRINCIPAL DESIGNER-ENVELOPE	TELEPHONE	Building Permit #
DOCUMENTATION AUTHOR	TELEPHONE	Checked by/Date Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA		CLIMATE ZONE
BUILDING TYPE	☐ NONRESIDENTIAL	☐ HIGH RISE RESIDENTIAL	☐ HOTEL/MOTEL GUEST ROOM
PHASE OF CONSTRUCTION	☐ NEW CONSTRUCTION	☐ ADDITION ☐ ALTERATION	☐ UNCONDITIONED (file affidavit)
METHOD OF ENVELOPE COMPLIANCE	☐ COMPONENT	☐ OVERALL ENVELOPE	☐ PERFORMANCE

STATEMENT OF COMPLIANCE

This Certificate of compliance lists the building features and performance specifications need to comply with Title 24, Parts 1 and 6 of the California Code of Regulations. This certificate applies only to building envelope requirements.

The documentation preparer hereby certifies that the documentation is accurate and complete.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Envelope Designer hereby certifies that the proposed building design represented in this set of construction documents is consistent with the other compliance forms and worksheets, with the specifications, and with any other calculations submitted with this permit application. The proposed building has been designed to meet the envelope requirements contained in sections 110, 116 through 118, and 140, 142, 143 or 149 of Title 24, Part 6.

Please check one:

☐ I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for its preparation; and that I am licensed in the State of California as a civil engineer or mechanical engineer, or I am a licensed architect.

☐ I affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code by section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ I affirm that I am eligible under Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described as exempt pursuant to Business and Professions Code Sections 5537, 5538 and 6737.1.

(These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

PRINCIPAL ENVELOPE DESIGNER-NAME	SIGNATURE	DATE	LIC. #

ENVELOPE MANDATORY MEASURES

Indicate location on plans of Note Block for Mandatory Measures ______________________

INSTRUCTIONS TO APPLICANT

For Detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the Nonresidential Manual published by the California Energy Commission.

ENV-1: Required on plans for all submittals. Part 2 may be incorporated in schedules on plans.

ENV-2: Used for all submittals; choose appropriate version depending on method of envelope compliance.

ENV-3: Optional. Use if default U-values are not used. Choose appropriate version for assembly U-value to be calculated.

CERTIFICATE OF COMPLIANCE (Part 2 of 2) ENV-1

PROJECT NAME	DATE

OPAQUE SURFACES

Surface Type	Construction Type (e.g., Block, Wood, Metal)	Area	U-Value	Azimuth	Tilt	Solar Gains Y/N	Form 3 Reference	Location/Comments (e.g., Suspended Ceiling, Demising, etc.)	NOTES TO FIELD - For Building Dept. Use Only
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			
						☐ ☐			

FENESTRATION SURFACES

Fenestration Type	Area	U-Value	Azimuth	SHGC	Glazing Type	Location / Comments	NOTES TO FIELD - For Bldg. Dept. Use Only

EXTERIOR SHADING

Fenestration #	Exterior Shade Type	SHGC	Window		Overhang				Left Fin			Right Fin		
			Height	Width	Length	Height	LExt.	RExt.	Dist.	Length	Height	Dist.	Length	Height

NOTES TO FIELD - For Building Department Use Only

ENVELOPE COMPONENT METHOD ENV-2

PROJECT NAME	DATE

WINDOW AREA CALCULATION SKYLIGHT AREA CALCULATION

GROSS WALL AREA (GWA)		DISPLAY PERI-METER (DP)	
GWA x 0.40		DP x 6	

GREATER OF

MAX. ALLOWABLE WINDOW AREA: ______

PROPOSED WINDOW AREA: ______

If the PROPOSED WINDOW AREA is greater than the MAXIMUM ALLOWABLE WINDOW AREA, go to another method.

ATRIUM HEIGHT ______ FT

IF ≤ 55 FT: 0.10 x ______ = ______

IF > 55 FT: 0.05 x ______ = ______

GROSS ROOF AREA — ALLOWED AREA

ACTUAL SKY. AREA: ______

If the ACTUAL SKYLIGHT AREA is greater than the ALLOWED SKYLIGHT AREA, go to another method.

OPAQUE SURFACES

ASSEMBLY NAME (eg. Wall-1, Floor-1)	TYPE (eg. Roof, Wall, Floor)	HEAT CAPACITY	INSULATION R-VALUE*		ASSEMBLY U-VALUE*			
			PROPOSED	MINIMUM ALLOWED	PROPOSED	TABLE VALUES? Y	N	MAXIMUM ALLOWED
						☐	☐	
						☐	☐	
						☐	☐	
						☐	☐	
						☐	☐	

* For each assembly type, meet the minimum insulation R-value or the maximum assembly U-value.

WINDOWS

WINDOW NAME (e.g., Window-1, Window-2)	ORIENTATION				U-VALUE		# OF PANES	PROPOSED RSHG						ALLOWED RSHG
	N	E	S	W	PROP.	ALLOW.		SHGC	H	V	H/V	OHF	PROP. RSHG	
	☐	☐	☐	☐										
	☐	☐	☐	☐										
	☐	☐	☐	☐										
	☐	☐	☐	☐										

SKYLIGHTS

SKYLIGHT NAME (e.g., Sky-1, Sky-2)	GLAZING		# OF PANES	U-VALUE		SOLAR HEAT GAIN COEFFICIENT	
	TRANSLUCENT	TRANSPARENT		PROPOSED	ALLOWED	PROPOSED	ALLOWED
	☐	☐					
	☐	☐					
	☐	☐					
	☐	☐					

OVERALL ENVELOPE METHOD (Part 1 of 5) ENV-2

PROJECT NAME	DATE

WINDOW AREA TEST

A. DISPLAY PERIMETER		FT × 6 =		SF DISPLAY AREA
B. GROSS EXTERIOR WALL AREA		SF × 0.40 =		SF 40% AREA
C. GROSS EXTERIOR WALL AREA		SF × 0.10 =		SF MINIMUM STANDARD AREA
D. ENTER LARGER OF A OR B				SF MAXIMUM STANDARD AREA
E. ENTER PROPOSED WINDOW AREA				SF PROPOSED AREA

IF E IS GREATER THAN D OR LESS THAN C, PROCEED TO THE NEXT CALCULATION FOR WINDOW AREA ADJUSTMENT. IF NOT, GO TO PART 2 OF 5.

1. IF E IS GREATER THAN D:

MAXIMUM STANDARD AREA		PROPOSED WINDOW AREA		WINDOW ADJUSTMENT FACTOR
	÷		=	

GO TO PART 5 TO CALCULATE ADJUSTED AREA

2. IF LESS THAN C:

MAXIMUM STANDARD AREA		PROPOSED WINDOW AREA (IF E = 0 ENTER 1)		WINDOW ADJUSTMENT FACTOR
	÷		=	

GO TO PART 5 TO CALCULATE ADJUSTED AREA

SKYLIGHT AREA TEST

ATRIUM HEIGHT [ ] FT

OR

IF ≤ 55 FT → 0.05 **IF > 55 FT** → 0.10

STANDARD %		GROSS ROOF AREA		STANDARD SKYLIGHT AREA
0.10	x		=	
0.05	x		=	

PROPOSED SKYLIGHT AREA [ ]

IF THE PROPOSED SKYLIGHT AREA IS GREATER THAN THE STANDARD SKYLIGHT AREA, PROCEED TO THE NEXT CALCULATION FOR THE SKYLIGHT AREA ADJUSTMENT. IF NOT, GO TO PART 2 OF 5.

1. IF PROPOSED SKYLIGHT AREA ≥ STANDARD SKYLIGHT AREA:

STANDARD SKYLIGHT AREA		PROPOSED SKYLIGHT AREA (IF E = 0 ENTER 1)		SKYLIGHT ADJUSTMENT FACTOR
	÷		=	

GO TO PART 5 TO CALCULATE ADJUSTED AREAS

OVERALL ENVELOPE METHOD (Part 2 of 5) ENV-2

PROJECT NAME	DATE

OVERALL HEAT LOSS

	A	B	C	D	E			F	G	H
		PROPOSED						STANDARD		
	ASSEMBLY NAME (e.g. Wall-1, Floor-1)	AREA	HEAT CAPACITY	U-VALUE	TABLE VALUES? Y	N	UA (B × D)	**AREA*** (Adjusted)	U-VALUE	**UA** (F × G)
WALLS					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
ROOFS/CEILINGS					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
FLOORS/SOFFITS					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
					☐	☐				
WINDOWS (# OF PANES)			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
SKYLIGHTS (# OF PANES)			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				
			N/A		☐	☐				

* If Window and/or Skylight Area Adjustment is Required, use adjusted areas from part 5 of 5.

TOTAL ◄ Column E shall be no greater than column H ► TOTAL

OVERALL ENVELOPE METHOD (Part 3 of 5) ENV-2

PROJECT NAME	DATE

OVERALL HEAT GAIN FROM CONDUCTION

	A	B	C	D	E			F	G	H	I	J
		PROPOSED							STANDARD			
	ASSEMBLY NAME (e.g. Wall-1, Floor-1)	AREA	TEMP. FACTOR	HEAT CAPACITY	U-VALUE	TABLE VALUES? Y	N	HEAT GAIN (B ×C ×E)	AREA* (Adjusted)	U-VALUE	TEMP. FACTOR	HEAT GAIN (G ×H ×I)
WALLS						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
ROOFS/CEILINGS						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
FLOORS/SOFFITS						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
						☐	☐					
WINDOWS	# OF PANES			N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
SKYLIGHTS	# OF PANES			N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
				N/A		☐	☐					
								SUBTOTAL				SUBTOTAL

* If Window and/or Skylight Area Adjustment is Required, use adjusted areas from part 5 of 5.

OVERALL ENVELOPE METHOD (Part 4 of 5) ENV-2

PROJECT NAME	DATE

OVERALL HEAT GAIN FROM RADIATION

	A	B	C	D	E	F		G	H	I	J	K	L	M
			PROPOSED								STANDARD			
						OVERHANG								
	WINDOW/SKYLIGHT NAME (e.g Window-1, Sky-1)	WEIGHTING FACTOR	AREA	SOLAR FACTOR	SHGC	H	V	H/V	OHF	HEAT GAIN (BxCx DxExH)	AREA (Adjusted)*	RSHG or SHGC**	SOLAR FACTOR	HEAT GAIN (B×J×K×L)
NORTH														
EAST														
SOUTH														
WEST														
SKYLIGHTS						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					
						N/A	N/A	N/A	N/A					

Proposed		Standard	
Part 4 Subtotal		Part 4 Subtotal	
Part 3 Subtotal		Part 3 Subtotal	
TOTAL		TOTAL	

* If Window and/or Skylight Area Adjustment is Required, use adjusted areas from part 5 of 5.

** Only SHGC is used for Skylights

Column **I** must be less than column **M**

OVERALL ENVELOPE METHOD (Part 5 of 5) ENV-2

PROJECT NAME	DATE

WINDOW AREA ADJUSTMENT CALCULATIONS

☐ CHECK IF NOT APPLICABLE (see Part 1 of 5)

A WALL NAME (e.g. Wall-1, Wall-2)	ORIENTATION N	 E	 S	 W	B GROSS AREA	C DOOR AREA	D WINDOW AREA	E WINDOW ADJUSTMENT FACTOR (From Part 1)	F ADJUSTED WINDOW AREA (D×E)	G ADJUSTED WALL AREA B-(F+C)
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
	☐	☐	☐	☐						
TOTALS:										

SKYLIGHT AREA ADJUSTMENT CALCULATIONS

☐ CHECK IF NOT APPLICABLE (see Part 1 of 5)

A ROOF NAME (e.g. Roof-1, Roof-2)	B GROSS AREA	C SKYLIGHT AREA	D SKYLIGHT ADJUSTMENT FACTOR (From Part 1)	E ADJUSTED SKYLIGHT AREA (C×D)	F ADJUSTED ROOF AREA (B - E)
TOTALS:					

PROPOSED MASONRY WALL ASSEMBLY — ENV-3

PROJECT NAME	DATE

COMPONENT DESCRIPTION

OUTSIDE | INSIDE

SKETCH OF ASSEMBLY

ASSEMBLY NAME

DESCRIPTION OF ASSEMBLY

WALL R-VALUE and HEAT CAPACITY

WALL UNIT THICKNESS		NOMINAL INCHES
MATERIAL TYPE		(LW CMU,MW CMU, NW CMU, CLAY UNIT, CLAY BRICK, CONCRETE.)
CORE TREATMENT		(SOLID, GROUTED, EMPTY, INSULATED, NA)
WALL R-VALUE		Rw (FROM TABLE B-4 or B-5)
WALL HEAT CAPACITY		HC (FROM TABLE B-4 or B-5)

FURRING/INSULATION LAYER (INSIDE and/or OUTSIDE IF ANY)

FURRING FRAMING MATERIAL		(WOOD, METAL, NONE)		
FURRING FRAMING SIZE		NOMINAL INCHES		ACTUAL INCHES
FURRING SPACE INSULATION		TYPE		R-VALUE
EXTERIOR INSULATING AREA		TYPE		R-VALUE

FURRING ASSEMBLY EFFECTIVE R-VALUE		**EXTERIOR INSULATING LAYER R-VALUE**		**INSULATION LAYER R-VALUE**	
	+		=		Rf
(FROM TABLE B-7)		(FROM MANUFACTURER)			

WALL ASSEMBLY R-VALUE and U-VALUE

INSULATION LAYER R-VALUE		**WALL R-VALUE**		**WALL ASSEMBLY R-VALUE**		**WALL ASSEMBLY U-VALUE**
	+		=		➜	
Rf		**Rw**		**Rt**		**1/Rt**

PROPOSED METAL FRAMED ASSEMBLY ENV-3

PROJECT NAME	DATE

COMPONENT DESCRIPTION

OUTSIDE

INSIDE

SKETCH OF ASSEMBLY

ASSEMBLY NAME

ASSEMBLY TYPE: Floor / Wall / Ceiling/Roof

FRAMING MATERIAL

FRAMING SIZE

FRAMING SPACING: 16” o. c.☐ 24” o. c.☐

INSULATION R-VALUE

CONSTRUCTION COMPONENTS

	DESCRIPTION	CAVITY R-VALUE (Rc)
	OUTSIDE SURFACE AIR FILM	
1		
2		
3		
4		
5		
6		
7		
	INSIDE SURFACE AIR FILM	

METAL FRAMING FACTOR			
Stud Spacing	Stud Depth	Insulation R-Value	Non-Mass Wall
16 o. c.	4”	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6”	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24 o. c.	4”	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6”	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308

SUBTOTAL		Rt
METAL FRAMING FACTOR		MFF
Rt × MFF		R-VALUE
INSULATING SHEATHING		R-VALUE
TOTAL R-VALUE		Rt
1/Rt		ASSEMBLY U-VALUE

COMMENTS

PROPOSED WOOD FRAME ASSEMBLY ENV-3

PROJECT NAME	DATE

COMPONENT DESCRIPTION

OUTSIDE INSIDE

SKETCH OF ASSEMBLY

ASSEMBLY NAME

ASSEMBLY TYPE (check one)
- Floor
- Wall
- Ceiling/Roof

FRAMING MATERIAL

FRAMING SIZE — Fr %: ______

FRAMING PERCENTAGE
- 15% (16" o. c. Wall
- 12% (24" o. c. Wall)
- 10% (16" o. c. Floor/Ceil.)
- 7% (24" o. c. Floor/Ceil.)

CONSTRUCTION COMPONENTS

	DESCRIPTION	R-VALUE		HEAT CAPACITY (optional)		
		CAVITY R-VALUE (Rc)	WOOD FRAME R-VALUE	A WALL WEIGHT lbs/sf	B SPECIFIC HEAT (Btu/F°•lbs)	HC (A×B) (Btu/F°•sf)
	OUTSIDE SURFACE AIR FILM					
1						
2						
3						
4						
5						
6						
7						
	INSIDE SURFACE AIR FILM					
	SUBTOTAL	Rc	Rf		TOTAL HC	

[1/Rc x 1 - (Fr%/100)] + [1/Rf x Fr%/100] = ASSEMBLY U-VALUE

COMMENTS

CERTIFICATE OF COMPLIANCE (Part 1 of 2) LTG-1

PROJECT NAME		DATE
PROJECT ADDRESS		
PRINCIPAL DESIGNER-LIGHTING	TELEPHONE	Building Permit #
DOCUMENTATION AUTHOR	TELEPHONE	Checked by/Date Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA	CLIMATE ZONE

BUILDING TYPE ☐ NONRESIDENTIAL ☐ HIGH RISE RESIDENTIAL ☐ HOTEL/MOTEL GUEST ROOM

PHASE OF CONSTRUCTION ☐ NEW CONSTRUCTION ☐ ADDITION ☐ ALTERATION ☐ UNCONDITIONED (file affidavit)

METHOD OF LIGHTING COMPLIANCE ☐ COMPLETE BLDG. ☐ AREA CATEGORY ☐ TAILORED ☐ PERFORMANCE

STATEMENT OF COMPLIANCE

This Certificate of Compliance lists the building features and performance specifications need to comply with Title 24, Parts 1 and 6 of the California Code of Regulations. This certificate applies only to building lighting requirements.

The documentation preparer hereby certifies that the documentation is accurate and complete.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Lighting Designer hereby certifies that the proposed building design represented in this set of construction documents is consistent with the other compliance forms and worksheets, with the specifications, and with any other calculations submitted with this permit application. The proposed building has been designed to meet the envelope requirements contained in the applicable parts of Sections 110, 119,130 through 132, 146, and 149 of Title 24, Part 6.

Please check one:

☐ I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for its preparation; and that I am licensed in the State of California as a civil engineer or electrical engineer, or I am a licensed architect.

☐ I affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code by section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ I affirm that I am eligible under Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described as exempt pursuant to Business and Professions Code Sections 5537,5538 and 6737.1.

(These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

PRINCIPAL LIGHTING DESIGNER-NAME	SIGNATURE	DATE	LIC. #

LIGHTING MANDATORY MEASURES

Indicate location on plans of Note Block for Mandatory Measure ______________________

INSTRUCTIONS TO APPLICANT

For detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the Nonresidential Manual published by the California Energy Commission.
LTG-1: Required on plans for all submittals. Part 2 may be incorporated in schedules on plans.
LTG-2: Required for all submittals.
LTG-3: Optional. Use only if lighting control credits are taken.
LTG-4: Optional. Use only if Tailored Method is used. Parts 2 and 3 used only if applicable.

CERTIFICATE OF COMPLIANCE (Part 2 of 2) LTG-1

PROJECT NAME	DATE

INSTALLED LIGHTING SCHEDULE

Code	LUMINAIRE DESCRIPTION	LAMPS Type DESCRIPTION	#	Watts Per Lamp	BALLASTS Type DESCRIPTION	#	Luminaire (Lamp + Ballast) #	Watts	TOTAL WATTS

SUBTOTAL FROM THIS PAGE	
BUILDING TOTAL	
LESS CONTROL CREDIT WATTS (From LTG-3)	
ADJUSTED ACTUAL WATTS	

MANDATORY AUTOMATIC CONTROLS

CONTROL LOCATION (Room #)	CONTROL IDENTIFICATION	CONTROL TYPE (Auto Time Switch, Exterior, etc.)	SPACE CONTROLED	NOTE TO FIELD

CONTROLS FOR CREDIT

CONTROL LOCATION (Room # or Dwg. #)	CONTROL IDENTIFICATION	CONTROL TYPE (Occupant, Daylight, Dimming, etc.)	LUMINAIRES CONTROLLED TYPE	# OF LUMINAIRES	NOTE TO FIELD

NOTES TO FIELD - For Building Department Use Only

LIGHTING COMPLIANCE SUMMARY LTG-2

PROJECT NAME	DATE

ACTUAL LIGHTING POWER

LUMINAIRE NAME	DESCRIPTION	NUMBER OF LUMINAIRES	WATTS PER LUMINAIRE (Including Ballast)	CEC DEFAULT? Y	N	TOTAL WATTS
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	
				☐	☐	

SUBTOTAL FROM THIS PAGE	
PLUS SUBTOTAL FROM CONTINUATION PAGE	
LESS CONTROL CREDIT WATTS (From LTG-3)	
ADJUSTED ACTUAL WATTS	

If not using the CEC Default value, please provide supporting documentation.

ALLOWED LIGHTING POWER (Choose One Method)

COMPLETE BUILDING METHOD

BUILDING CATEGORY (From § 146(b) Table 1-M)	WATTS PER SF	COMPLETE BLDG. AREA	ALLOWED WATTS

AREA CATEGORY METHOD

AREA CATEGORY (From § 146(b) Table 1-N)	WATTS PER SF	AREA (SF)	ALLOWED WATTS
	TOTALS	AREA	WATTS

TAILORED METHOD

TOTAL ALLOWED WATTS (From LTG-4. or from Computer Run)

LIGHTING CONTROLS CREDIT WORKSHEET LTG-3

PROJECT NAME	DATE

WORKSHEET

A	B	C	D	E	F	G	H	I
			ROOM	DAYLIGHTING		WATTS OF	LIGHTING	CONTROL
ROOM # ZONE ID	LIGHTING CONTROL DESCRIPTION	PLANS REF.	AREA (SF)	ROOM RATIO*	GLAZING VLT	CONTROL LIGHTING	ADJUSTMENT FACTOR	CREDIT WATTS (G X H)

PAGE TOTAL →

BUILDING TOTAL →

Enter on LTG-2: Actual lighting Power calculation

*For windows, use the Window Wall Ratio for the room. For skylights, use the Skylight-to Roof ratio for the room.

TAILORED LPD SUMMARY and WORKSHEET (Part 1 of 3) LTG-4

PROJECT NAME	DATE

TAILORED LPD SUMMARY

1. Watts for Illuminance Categories A-D (from column G below) → ______ WATTS

2.Watts for Illuminance Categories E-I (from LTG-4 Part 2) → ______ WATTS

3. Watts for Display Lighting (from LTG-4 Parts 2 & 3)

______ + ______ + ______ = ______ WATTS

Public Area Display | Sales Feature Floor Display | Sales Feature Wall Display

4. Total Allowed Watts (lines 1+2+3) → ______ WATTS

TAILORED LPD - Illuminance Categories A, B, C and D and Gross Sales Floor Area

A ROOM NUMBER	B TASK/ACTIVITY	C ILLUMINANCE CATEGORY	D ROOM CAVITY RATIO	E FLOOR AREA	F ALLOWED LPD	G ALLOWED WATTS (E X F)
		PAGE TOTAL →				
		BUILDING TOTAL →				
				SF		WATTS

TAILORED LPD SUMMARY and WORKSHEET (Part 2 of 3) LTG-4

PROJECT NAME	DATE

TAILORED LPD - Illuminance Categories E, F, G, H, I and Gross Sales Wall Area

A	B	C	D	E	F	G	H	I	J	K	L
				ALLOTTED WATTS			DESIGN WATTS				
TASK / ACTIVITY	Illum. Cat.	RCR (If E)	Notes*	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (E X F)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (I X J)	**ALLOWED WATTS** (Min. G or K)

* Enter Mounting Height or Throw Distance if applicable.

PAGE TOTAL →

BUILDING TOTAL →

TAILORED LPD - Public Area Displays

A	B	C	D	E	F	G	H	I	J	K
			ALLOTTED WATTS			DESIGN WATTS				
TASK / ACTIVITY	THROW DISTANCE	MOUNT. HEIGHT	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (E X F)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (H X I)	**ALLOWED WATTS** (Min. F or J)

TOTAL AREA PUBLIC DISPLAYS ____ SF

TOTAL ____ WATTS

PLANE OF PUBLIC DISPLAY AREA ____ X 0.1 = ____ MAXIMUM AREA PUBLIC DISPLAYS (SF)

TAILORED LPD SUMMARY and WORKSHEET (Part 3 of 3) LTG-4

PROJECT NAME	DATE

TAILORED LPD - Sales Feature Floor Displays

A	B	C	D	E	F	G	H	I	J	K
			ALLOTTED WATTS			DESIGN WATTS				
TASK / ACTIVITY	THROW DISTANCE	MOUNT. HEIGHT	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (D X E)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (H X I)	**ALLOWED WATTS** (Min. F or J)

TOTAL AREA FLOOR DISPLAYS [ ] SF — TOTAL WATTS [ ]

GROSS SALES FLOOR AREA [ ] X 0.1 = [ ] MAXIMUM AREA FLOOR DISPLAYS (SF)

TAILORED LPD - Sales Feature Wall Displays

A	B	C	D	E	F	G	H	I	J
		ALLOTTED WATTS			DESIGN WATTS				
TASK ACTIVITY	THROW DISTANCE	TASK AREA (sf)	ALLOWED LPD	ALLOTTED WATTS (C X D)	LUMIN. CODE	QTY.	WATTS/ LUMIN.	DESIGN WATTS (G XH)	**ALLOWED WATTS** (Min. E or I)

TOTAL AREA WALL DISPLAYS [ ] SF — TOTAL WATTS [ ]

GROSS SALES WALL AREA [ ] X 0.1 = [ ] MAXIMUM AREA WALL DISPLAYS (SF)

ROOM CAVITY RATIO WORKSHEET (RCR ≥ 3.5) LTG-5

PROJECT NAME		FOR ENFORCEMENT AGENCY USE ONLY	
DOCUMENTATION AUTHOR	DATE	PLAN CHECKED BY	DATE

RECTANGULAR SPACES

A Room Number	B Task/Activity Description	C Room Length (L)	D Room Width (W)	E Room Cavity Height (H)	F Room Cav. Ratio 5 x H x (L+W) / (L x W)

NON-RECTANGULAR SPACES

A Room Number	B Task/Activity Description	C Room Area (A)	D Room Perimeter (P)	E Room Cavity Height (H)	F Room Cav. Ratio 2.5 x H x P /A

CERTIFICATE OF COMPLIANCE (Part 1 of 2) MECH-1

PROJECT NAME		DATE
PROJECT ADDRESS		
PRINCIPAL DESIGNER-MECHANICAL	TELEPHONE	Building Permit #
DOCUMENTATION AUTHOR	TELEPHONE	Checked by/Date Enforcement Agency Use

GENERAL INFORMATION

DATE OF PLANS	BUILDING CONDITIONED FLOOR AREA

BUILDING TYPE ☐ NONRESIDENTIAL ☐ HIGH RISE RESIDENTIAL ☐ HOTEL/MOTEL GUEST ROOM

PHASE OF CONSTRUCTION ☐ NEW CONSTRUCTION ☐ ADDITION ☐ ALTERATION ☐ UNCONDITIONED (file affidavit)

METHOD OF MECHANICAL COMPLIANCE ☐ PRESCRIPTIVE ☐ PERFORMANCE

PROOF OF ENVELOPE COMPLIANCE ☐ PREVIOUS ENVELOPE PERMIT ☐ ENVELOPE COMPLIANCE ATTACHED

STATEMENT OF COMPLIANCE

This Certificate of Compliance lists the building features and performance specifications need to comply with Title 24, Parts 1 and 6 of the California Code of Regulations. This certificate applies only to building mechanical requirements.

The documentation preparer hereby certifies that the documentation is accurate and complete.

DOCUMENTATION AUTHOR	SIGNATURE	DATE

The Principal Mechanical Designer hereby certifies that the proposed building design represented in this set of construction documents is consistent with the other compliance forms and worksheets, with the specifications, and with any other calculations submitted with this permit application. The proposed building has been designed to meet the mechanical requirements contained in the applicable parts of Sections 110 through 115, 120 through 124, 140 through 142, 144 and 145.

Please check one:

☐ I hereby affirm that I am eligible under the provisions of Division 3 of the Business and Professions Code to sign this document as the person responsible for it's preparation; and that I am licensed in the State of California as a civil engineer or mechanical engineer, or I am a licensed architect.

☐ I affirm that I am eligible under the exemption to Division 3 of the Business and Professions Code by Section 5537.2 or 6737.3 to sign this document as the person responsible for its preparation; and that I am a licensed contractor performing this work.

☐ I affirm that I am eligible under the exemption to Division 3 of the Business and Professions Code to sign this document because it pertains to a structure or type of work described pursuant to Business and Professions Code sections 5537, 5538, and 6737.1.

(These sections of the Business and Professions Code are printed in full in the Nonresidential Manual.)

PRINCIPAL MECHANICAL DESIGNER-NAME	SIGNATURE	DATE	LIC. #

MECHANICAL MANDATORY MEASURES

Indicate location on plans of Note Block for Mandatory Measures ______________________

INSTRUCTIONS TO APPLICANT

For Detailed instructions on the use of this and all Energy Efficiency Standards compliance forms, please refer to the Nonresidential Manual published by the California Energy Commission.
MECH-1: Required on plans for all submittals. Part 2 may be incorporated in schedules on plans.
MECH-2: Required for all submittals, but may be incorporated in schedules on plans.
MECH-3: Required for all submittals unless required ventilation rates and airflows are shown on plans, See 4.3.4.
MECH-4: Required for all prescriptive submittals.

CERTIFICATE OF COMPLIANCE (Part 2 of 2) MECH-1

PROJECT NAME	DATE

SYSTEM FEATURES

SYSTEM NAME	MECHANICAL SYSTEMS			NOTE TO FIELD Bldg. Dept. Use
TIME CONTROL				
SETBACK CONTROL				
ISOLATION ZONES				
HEAT PUMP THERMOSTAT?				
ELECTRIC HEAT?				
FAN CONTROL				
VAV MINIMUM POSITION CONTROL?				
SIMULTANEOUS HEAT/COOL?				
HEAT AND COOL SUPPLY RESET?				
VENTILATION				
OUTDOOR DAMPER CONTROL?				
ECONOMIZER TYPE				
DESIGN O.A. CFM (MECH-3, COLUMN H)				
HEATING EQUIPMENT TYPE				
HIGH EFFICIENCY? / IF YES ENTER EFF. #				
MAKE AND MODEL NUMBER				
COOLING EQUIPMENT TYPE				
HIGH EFFICIENCY? / IF YES ENTER EFF. #				
MAKE AND MODEL NUMBER				
PIPE INSULATION REQUIRED?				
PIPE TYPE (SUPPLY, RETURN, ETC.)				
HEATING DUCT LOCATION / R-VALUE				
COOLING DUCT LOCATION / R-VALUE				
DUCT TAPE ALLOWED?				

CODE TABLES: Enter code from table below into columns above.

Question	Code
HEAT PUMP THERMOSTAT?	Y: Yes N: No
ELECTRIC HEAT?	
VAV MINIMUM POSITION CONTROL?	
SIMULTANEOUS HEAT/COOL?	
HEAT AND COOL SUPPLY RESET?	
HIGH EFFICIENCY?	
DUCT TAPE ALLOWED?	
PIPE INSULATION REQUIRED?	

TIME CONTROL	SETBACK CTRL.	ISOLATION ZONES	FAN CONTROL
S: Prog. Switch O: Occupancy Sensor M: Manual Timer	H: Heating C: Cooling B: Both	Enter number of Isolation Zones	I: Inlet Vanes P: Variable Pitch V: VFD O: Other C: Curve

VENTILATION	OUTDOOR DAMPER	ECONOMIZER	DESIGN O.A. CFM
B: Air Balance C: Outside Air Cert. M: Outside Air Measure D: Demand Control N: Natural	A: Auto G: Gravity	A: Air W: Water N: Not Required	Enter Design Outdoor Air CFM. Note: This shall be no less than Column H on MECH-3.

MECHANICAL EQUIPMENT SUMMARY (Part 1 of 2) MECH-2

PROJECT NAME	DATE

CHILLER AND TOWER SUMMARY

					PUMPS					
Equipment Name	Equipment Type	Qty.	Efficiency	Tons	Total Qty.	GPM	BHP	Motor Eff.	Drive Eff.	Pump Control

DHW / BOILER SUMMARY

								TANK INSUL.
System Name	System Type	Distribution Type	Qty.	Rated Input	Vol. (Gals.)	Energy Factor or Recovery Efficiency	Standby Loss or Pilot	External R-Val

CENTRAL SYSTEM RATINGS

			HEATING			COOLING			
System Name	System Type	Qty.	Output	Aux. kW	Efficiency	Output	Sensible	Efficiency	Economizer Type

CENTRAL FAN SUMMARY

			SUPPLY FAN				RETURN FAN			
System Name	Fan Type	Motor Location	CFM	BHP	Motor Eff.	Drive Eff.	CFM	BHP	Motor Eff.	Drive Eff.

MECHANICAL EQUIPMENT SUMMARY (Part 2 of 2) MECH-2

PROJECT NAME	DATE

VAV SUMMARY

Zone Name	VAV					FAN					BASEBOARD	
	System Type	Qty.	Min. CFM Ratio	Reheat? Type	ΔT	Flow Ratio	CFM	BHP	Motor Eff.	Drive Eff.	Type	Output

EXHAUST FAN SUMMARY

EXHAUST FAN						EXHAUST FAN					
Room Name	Qty.	CFM	BHP	Motor Eff.	Drive Eff.	Room Name	Qty.	CFM	BHP	Motor Eff.	Drive Eff.

MECHANICAL VENTILATION MECH-3

PROJECT NAME	DATE

MECHANICAL VENTILATION

A	B	C	D	E	F	G	H	I	J	K
	AREA BASIS			OCCUPANCY BASIS			REQ'D.	DESIGN		
ZONE/ SYSTEM	COND AREA (SF)	CFM PER SF	MIN. CFM (B X C)	NO. OF PEOPLE	CFM PER PERSON	MIN. CFM (E X F)	**O.A.** (MAX. OF D OR G)	**OUTDOOR AIR CFM**	**VAV MIN. CFM**	**TRANSFER AIR CFM**
	Totals (For MECH-4)									

C Minimum ventilation rate per Section § 121, Table 1-F.

E Based on expected number of occupants or at least 50% of Chapter 10 1997 UBC occupant density

I Must be greater than or equal to H, or use Transfer Air. Design outdoor air includes ventilation from supply air system & exhaust fans which Operate at design conditions.

K Must be greater than or equal to (H - I), and, for VAV, greater than or equal to (H - J).

MECHANICAL SIZING AND FAN POWER — MECH-4

PROJECT NAME	DATE
SYSTEM NAME	FLOOR AREA

NOTE: Provide one copy of this form for each mechanical system when using the Prescriptive Approach.

SIZING and EQUIPMENT SELECTION

			COOLING	HEATING
1. DESIGN CONDITIONS:				
- OUTDOOR, DRY BULB TEMPERATURE		(APPENDIX C)		
- OUTDOOR, WET BULB TEMPERATURE		(APPENDIX C)		
- INDOOR, DRY BULB TEMPERATURE		(See Chap. 8, ASHRAE handbook, 1993)		
2. SIZING				
- DESIGN OUTDOOR AIR		CFM (MECH 3; COLUMN I)		
- ENVELOPE LOAD		Btu/Hr (ENV-2 Part 2 of 5 Column E)		
- LIGHTING		W / SF (Adjusted Actual Watts-LTG-2)		
- PEOPLE		# OF PEOPLE (MECH 3; COLUMN E)		
- MISCELLANEOUS EQUIPMENT		WATTS / SF		
- OTHER				
1)				
2)				
3)				
		TOTALS		
OTHER LOADS/SAFETY FACTOR (1.21 for cooling, 1.43 for heating)				
MAXIMUM ADJUSTED LOAD (TOTALS FROM ABOVE x OTHER LOAD SAFETY FACTOR)				

3. SELECTION:

	COOLING	HEATING
INSTALLED EQUIPMENT CAPACITY	KBtu / Hr	KBtu / Hr

IF INSTALLED CAPACITY EXCEEDS MAXIMUM ADJUSTED LOAD, EXPLAIN ______________________

FAN POWER CONSUMPTION

A	B	C	D	E	F	G
FAN DESCRIPTION	**DESIGN BRAKE HP**	**EFFICIENCY** MOTOR	DRIVE	**NUMBER OF FANS**	**PEAK WATTS** B x E x 746 / (C x D)	**CFM** (Supply Fans)
				TOTALS		

NOTE: Include only fan systems exceeding 25 HP (see § 144). Total Fan System Power Demand may not exceed 0.8 Watts/CFM for constant volume systems or 1.25 Watts/CFM for VAV systems.

TOTAL FAN SYSTEM POWER DEMAND WATTS / CFM ______ Col. F / Col. G

B: Materials Reference

TABLE	TITLE	PAGE
________	*Framing Calculation Approaches/Tables*	B-3
Table B-1	*ASHRAE Thermal Properties Tables*	B-4
Table B-2	*Framed Wall Assembly U-values*	B-26
Table B-2a	*Solar Heat Gain Coefficients Used for Exterior Shading*	B-28
Table B-3	*Metal Framing Factors*	B-29
Table B-4	*Properties of Hollow Unit Masonry Walls*	B-30
Table B-5	*Properties of Solid Unit Masonry And Solid Concrete Walls*	B-31
Table B-6	*Effective R-values for Interior Insulation Layers on Structural Mass Walls*	B-32
Table B-7	*Framed Wall/Floor/Ceiling Assembly U-values*	B-33
EZFRAME	*Computer Modeling of Framed Assemblies Information*	B-83
Table B-8A	*Fan Motor Efficiencies (< 1 HP)*	B-84
Table B-8B	*Fan Motor Efficiencies (1 HP And Over)*	B-85
Table B-9	*Minimum Mechanical Equipment Efficiencies*	B-86
Table B-10	*Illuminance Categories*	B-93
Table B-11	*Default Lamp/Ballast Wattages*	B-104

Framing Calculation Approaches/Tables

When showing compliance with the building energy efficiency standard, the envelope assemblies U-value must meet the requirements of the standard. For wood and metal framed, light and heavy mass walls the tabulated default values or calculation methods presented in this section to determine the U-value of an assembly can be used in compliance.

U-VALUE CALCULATION PROCEDURE FOR CALCULATING METAL FRAMED ASSEMBLIES ***B-4***

This section includes sample calculations for metal framed assemblies and all of the ASHRAE methods, including the parallel path, zonal method, and isothermal plane method. To calculate the U-value of more complex assemblies or develop a better understanding of heat transfer through different types of construction assemblies users may reference this section.

FRAMED WALL ASSEMBLY U-VALUES ***B-26-27***

If the wall assembly is very generic or there is no need to take advantage or evaluate specific components of a construction assembly, the default U-values in Table B-2 can be used. Use of Table B-2 will significantly simplify compliance and save considerable time, however, the assumption used to develop these default tables are very conservative.

METAL FRAMING FACTORS ***B-29***

This table includes values reference in Chapter 3 to be used to adjust U-value calculations using a parallel method when metal framing is used.

PROPERTIES OF MASONARY WALLS ***B-30-32***

These tables list the U-value and Heat Capacity of basic types of masonry block construction. They also include the effects of insulation placed on block walls.

FRAMED WALL/FLOOR/CEILING ASSEMBLIES U-VALUES ***B-33-82***

This table refers to Table B7 that includes diagrams and assembly U-value calculation for some basic ceiling and floor assemblies.

COMPUTER MODELING OF FRAMED ASSEMBLIES ***B-83***

This Commission has developed the EZFRAME program to automate ASHRAE procedures in order to help the building community in calculating the U-values of wood and metal framed assemblies with a higher degree of accuracy and speed. The output forms of this program can be used as part of a residential or nonresidential submittal.

CHAPTER 22

THERMAL AND WATER VAPOR TRANSMISSION DATA

Building Envelopes 22.1
Calculating Overall Thermal Resistances 22.3
Mechanical and Industrial Systems 22.17
Calculating Heat Flow for Buried Pipelines 22.19

THIS chapter presents thermal and water vapor transmission data based on steady-state or equilibrium conditions. Chapter 3 covers heat transfer under transient or changing temperature conditions. Chapter 20 discusses selection of insulation materials and procedures for determining overall thermal resistances by simplified methods.

BUILDING ENVELOPES

Thermal Transmission Data for Building Components

The steady-state thermal resistances (R-values) of building components (walls, floors, windows, roof systems, etc.) can be calculated from the thermal properties of the materials in the component; or the heat flow through the assembled component can be measured directly with laboratory equipment such as the guarded hot box (ASTM *Standard* C 236) or the calibrated hot box (ASTM *Standard* C 976).

Tables 1 through 6 list thermal values, which may be used to calculate thermal resistances of building walls, floors, and ceilings. The values shown in these tables were developed under ideal conditions. In practice, overall thermal performance can be reduced significantly by such factors as improper installation and shrinkage, settling, or compression of the insulation (Tye and Desjarlais 1983, Tye 1985, 1986).

Most values in these tables were obtained by accepted ASTM test methods described in ASTM *Standards* C 177 and C 518 for materials and ASTM *Standards* C 236 and C 976 for building envelope components. Because commercially available materials vary, not all values apply to specific products. (Previous editions of the handbook can be consulted for data on materials no longer commercially available.)

The most accurate method of determining the overall thermal resistance for a combination of building materials assembled as a building envelope component is to test a representative sample by a hot box method. However, all combinations may not be conveniently or economically tested in this manner. For many simple constructions, calculated R-values agree reasonably well with values determined by hot box measurement.

The performance of materials fabricated in the field is especially subject to the quality of workmanship during construction and installation. Good workmanship becomes increasingly important as the insulation requirement becomes greater. Therefore, some engineers include additional insulation or other safety factors based on experience in their design.

Figure 1 shows how convection affects surface conductance of several materials. Other tests on smooth surfaces show that the average value of the convection part of conductance decreases as the length of the surface increases.

Table 1 Surface Conductances and Resistances for Air

Position of Surface	Direction of Heat Flow	Surface Emittance, ϵ: Non-reflective $\epsilon = 0.90$ h_i	R	Reflective $\epsilon = 0.20$ h_i	R	Reflective $\epsilon = 0.05$ h_i	R
STILL AIR							
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32
Sloping—45°	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Sloping—45°	Downward	1.32	0.76	0.60	1.67	0.45	2.22
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55
MOVING AIR (Any position)		h_o	R	h_o	R	h_o	R
15-mph Wind (for winter)	Any	6.00	0.17	—	—	—	—
7.5-mph Wind (for summer)	Any	4.00	0.25	—	—	—	—

Notes:
1. Surface conductance h_i and h_o measured in Btu/h · ft^2 · °F; resistance R in °F · ft^2 · h/Btu.
2. No surface has both an air space resistance value and a surface resistance value.
3. For ventilated attics or spaces above ceilings under summer conditions (heat flow down), see Table 5.
4. Conductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10°F and for surface temperatures of 70°F.
5. See Chapter 3 for more detailed information, especially Tables 5 and 6, and see Figure 1 for additional data.
6. Condensate can have a significant impact on surface emittance (see Table 3).

The preparation of this chapter is assigned to TC 4.4, Thermal Insulation and Moisture Retarders.

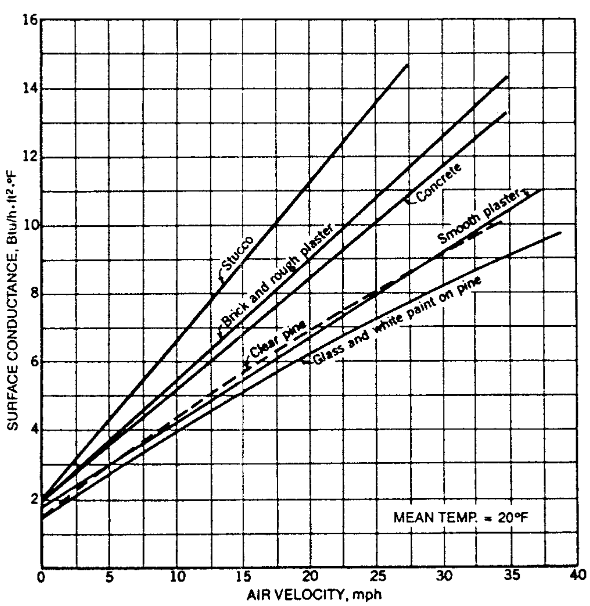


Fig. 1. Surface Conductance for Different 12-Inch-Square Surfaces as Affected by Air Movement

Table 2 Thermal Resistances of Plane Air Spaces[a,b,c], °F·ft²·h/Btu

Position of Air Space	Direction of Heat Flow	Air Space Mean Temp.[d], °F	Air Space Temp. Diff.[d], °F	0.5-in. Air Space[c] Effective Emittance ϵ_{eff}[d,e] 0.03	0.05	0.2	0.5	0.82	0.75-in. Air Space[c] Effective Emittance ϵ_{eff}[d,e] 0.03	0.05	0.2	0.5	0.82
		90	10	2.13	2.03	1.51	0.99	0.73	2.34	2.22	1.61	1.04	0.75
		50	30	1.62	1.57	1.29	0.96	0.75	1.71	1.66	1.35	0.99	0.77
		50	10	2.13	2.05	1.60	1.11	0.84	2.30	2.21	1.70	1.16	0.87
Horiz.	Up ↑	0	20	1.73	1.70	1.45	1.12	0.91	1.83	1.79	1.52	1.16	0.93
		0	10	2.10	2.04	1.70	1.27	1.00	2.23	2.16	1.78	1.31	1.02
		−50	20	1.69	1.66	1.49	1.23	1.04	1.77	1.74	1.55	1.27	1.07
		−50	10	2.04	2.00	1.75	1.40	1.16	2.16	2.11	1.84	1.46	1.20
		90	10	2.44	2.31	1.65	1.06	0.76	2.96	2.78	1.88	1.15	0.81
		50	30	2.06	1.98	1.56	1.10	0.83	1.99	1.92	1.52	1.08	0.82
45°		50	10	2.55	2.44	1.83	1.22	0.90	2.90	2.75	2.00	1.29	0.94
Slope	Up ↗	0	20	2.20	2.14	1.76	1.30	1.02	2.13	2.07	1.72	1.28	1.00
		0	10	2.63	2.54	2.03	1.44	1.10	2.72	2.62	2.08	1.47	1.12
		−50	20	2.08	2.04	1.78	1.42	1.17	2.05	2.01	1.76	1.41	1.16
		−50	10	2.62	2.56	2.17	1.66	1.33	2.53	2.47	2.10	1.62	1.30
		90	10	2.47	2.34	1.67	1.06	0.77	3.50	3.24	2.08	1.22	0.84
		50	30	2.57	2.46	1.84	1.23	0.90	2.91	2.77	2.01	1.30	0.94
		50	10	2.66	2.54	1.88	1.24	0.91	3.70	3.46	2.35	1.43	1.01
Vertical	Horiz. →	0	20	2.82	2.72	2.14	1.50	1.13	3.14	3.02	2.32	1.58	1.18
		0	10	2.93	2.82	2.20	1.53	1.15	3.77	3.59	2.64	1.73	1.26
		−50	20	2.90	2.82	2.35	1.76	1.39	2.90	2.83	2.36	1.77	1.39
		−50	10	3.20	3.10	2.54	1.87	1.46	3.72	3.60	2.87	2.04	1.56
		90	10	2.48	2.34	1.67	1.06	0.77	3.53	3.27	2.10	1.22	0.84
		50	30	2.64	2.52	1.87	1.24	0.91	3.43	3.23	2.24	1.39	0.99
45°		50	10	2.67	2.55	1.89	1.25	0.92	3.81	3.57	2.40	1.45	1.02
Slope	Down ↘	0	20	2.91	2.80	2.19	1.52	1.15	3.75	3.57	2.63	1.72	1.26
		0	10	2.94	2.83	2.21	1.53	1.15	4.12	3.91	2.81	1.80	1.30
		−50	20	3.16	3.07	2.52	1.86	1.45	3.78	3.65	2.90	2.05	1.57
		−50	10	3.26	3.16	2.58	1.89	1.47	4.35	4.18	3.22	2.21	1.66
		90	10	2.48	2.34	1.67	1.06	0.77	3.55	3.29	2.10	1.22	0.85
		50	30	2.66	2.54	1.88	1.24	0.91	3.77	3.52	2.38	1.44	1.02
		50	10	2.67	2.55	1.89	1.25	0.92	3.84	3.59	2.41	1.45	1.02
Horiz.	Down ↓	0	20	2.94	2.83	2.20	1.53	1.15	4.18	3.96	2.83	1.81	1.30
		0	10	2.96	2.85	2.22	1.53	1.16	4.25	4.02	2.87	1.82	1.31
		−50	20	3.25	3.15	2.58	1.89	1.47	4.60	4.41	3.36	2.28	1.69
		−50	10	3.28	3.18	2.60	1.90	1.47	4.71	4.51	3.42	2.30	1.71

Position of Air Space	Direction of Heat Flow	Air Space Mean Temp.[d], °F	Air Space Temp. Diff.[d], °F	1.5-in. Air Space[c] 0.03	0.05	0.2	0.5	0.82	3.5-in. Air Space[c] 0.03	0.05	0.2	0.5	0.82
		90	10	2.55	2.41	1.71	1.08	0.77	2.84	2.66	1.83	1.13	0.80
		50	30	1.87	1.81	1.45	1.04	0.80	2.09	2.01	1.58	1.10	0.84
		50	10	2.50	2.40	1.81	1.21	0.89	2.80	2.66	1.95	1.28	0.93
Horiz.	Up ↑	0	20	2.01	1.95	1.63	1.23	0.97	2.25	2.18	1.79	1.32	1.03
		0	10	2.43	2.35	1.90	1.38	1.06	2.71	2.62	2.07	1.47	1.12
		−50	20	1.94	1.91	1.68	1.36	1.13	2.19	2.14	1.86	1.47	1.20
		−50	10	2.37	2.31	1.99	1.55	1.26	2.65	2.58	2.18	1.67	1.33
		90	10	2.92	2.73	1.86	1.14	0.80	3.18	2.96	1.97	1.18	0.82
		50	30	2.14	2.06	1.61	1.12	0.84	2.26	2.17	1.67	1.15	0.86
45°		50	10	2.88	2.74	1.99	1.29	0.94	3.12	2.95	2.10	1.34	0.96
Slope	Up ↗	0	20	2.30	2.23	1.82	1.34	1.04	2.42	2.35	1.90	1.38	1.06
		0	10	2.79	2.69	2.12	1.49	1.13	2.98	2.87	2.23	1.54	1.16
		−50	20	2.22	2.17	1.88	1.49	1.21	2.34	2.29	1.97	1.54	1.25
		−50	10	2.71	2.64	2.23	1.69	1.35	2.87	2.79	2.33	1.75	1.39
		90	10	3.99	3.66	2.25	1.27	0.87	3.69	3.40	2.15	1.24	0.85
		50	30	2.58	2.46	1.84	1.23	0.90	2.67	2.55	1.89	1.25	0.91
		50	10	3.79	3.55	2.39	1.45	1.02	3.63	3.40	2.32	1.42	1.01
Vertical	Horiz. →	0	20	2.76	2.66	2.10	1.48	1.12	2.88	2.78	2.17	1.51	1.14
		0	10	3.51	3.35	2.51	1.67	1.23	3.49	3.33	2.50	1.67	1.23
		−50	20	2.64	2.58	2.18	1.66	1.33	2.82	2.75	2.30	1.73	1.37
		−50	10	3.31	3.21	2.62	1.91	1.48	3.40	3.30	2.67	1.94	1.50
		90	10	5.07	4.55	2.56	1.36	0.91	4.81	4.33	2.49	1.34	0.90
		50	30	3.58	3.36	2.31	1.42	1.00	3.51	3.30	2.28	1.40	1.00
45°		50	10	5.10	4.66	2.85	1.60	1.09	4.74	4.36	2.73	1.57	1.08
Slope	Down ↘	0	20	3.85	3.66	2.68	1.74	1.27	3.81	3.63	2.66	1.74	1.27
		0	10	4.92	4.62	3.16	1.94	1.37	4.59	4.32	3.02	1.88	1.34
		−50	20	3.62	3.50	2.80	2.01	1.54	3.77	3.64	2.90	2.05	1.57
		−50	10	4.67	4.47	3.40	2.29	1.70	4.50	4.32	3.31	2.25	1.68
		90	10	6.09	5.35	2.79	1.43	0.94	10.07	8.19	3.41	1.57	1.00
		50	30	6.27	5.63	3.18	1.70	1.14	9.60	8.17	3.86	1.88	1.22
		50	10	6.61	5.90	3.27	1.73	1.15	11.15	9.27	4.09	1.93	1.24
Horiz.	Down ↓	0	20	7.03	6.43	3.91	2.19	1.49	10.90	9.52	4.87	2.47	1.62
		0	10	7.31	6.66	4.00	2.22	1.51	11.97	10.32	5.08	2.52	1.64
		−50	20	7.73	7.20	4.77	2.85	1.99	11.64	10.49	6.02	3.25	2.18
		−50	10	8.09	7.52	4.91	2.89	2.01	12.98	11.56	6.36	3.34	2.22

[a]See Chapter 20, section Factors Affecting Heat Transfer across Air Spaces. Thermal resistance values were determined from the relation, $R = 1/C$, where $C = h_c + \epsilon_{eff} h_r$, h_c is the conduction-convection coefficient, $\epsilon_{eff} h_r$ is the radiation coefficient $\cong 0.00686\,\epsilon_{eff}\,[(t_m + 460)/100]^3$, and t_m is the mean temperature of the air space. Values for h_c were determined from data developed by Robinson *et al.* (1954). Equations (5) through (7) in Yarbrough (1983) show the data in Table 2 in analytic form. For extrapolation from Table 2 to air spaces less than 0.5 in. (as in insulating window glass), assume $h_c = 0.159(1 + 0.0016\,t_m)/l$ where l is the air space thickness in inches, and h_c is heat transfer through the air space only.

[b]Values are based on data presented by Robinson *et al.* (1954). (Also see Chapter 3, Tables 3 and 4, and Chapter 39). Values apply for ideal conditions, *i.e.*, air spaces of uniform thickness bounded by plane, smooth, parallel surfaces with no air leakage to or from the space. When accurate values are required, use overall U-factors determined through calibrated hot box (ASTM C 976) or guarded hot box (ASTM C 236) testing. Thermal resistance values for multiple air spaces must be based on careful estimates of mean temperature differences for each air space.

[c]A single resistance value cannot account for multiple air spaces; each air space requires a separate resistance calculation that applies only for the established boundary conditions. Resistances of horizontal spaces with heat flow downward are substantially independent of temperature difference.

[d]Interpolation is permissible for other values of mean temperature, temperature difference, and effective emittance ϵ_{eff}. Interpolation and moderate extrapolation for air spaces greater than 3.5 in. are also permissible.

[e]Effective emittance ϵ_{eff} of the air space is given by $1/\epsilon_{eff} = 1/\epsilon_1 + 1/\epsilon_2 - 1$, where ϵ_1 and ϵ_2 are the emittances of the surfaces of the air space (see Table 3).

Vapor retarders, outlined in Chapters 20 and 21, require special attention. Moisture from condensation or other sources may reduce the thermal resistance of insulation, but the effect of moisture must be determined for each material. For example, some materials with large air spaces are not affected significantly if the moisture content is less than 10% by weight, while the effect of moisture on other materials is approximately linear.

Ideal conditions of components and installations are assumed in calculating overall R-values (*i.e.*, insulating materials are of uniform nominal thickness and thermal resistance, air spaces are of uniform thickness and surface temperature, moisture effects are not involved, and installation details are in accordance with design). The National Bureau of Standards' Building Materials and Structures Report BMS 151 shows that measured values differ from calculated values for certain insulated constructions. For this reason, some engineers decrease the calculated R-values a moderate amount to account for departures of constructions from requirements and practices.

Tables 2 and 3 give values for well-sealed systems constructed with care. Field applications can differ substantially from laboratory test conditions. Air gaps in these insulation systems can seriously degrade thermal performance as a result of air movement due to both natural and forced convection. Sabine *et al.* (1975) found that the tabular values are not necessarily additive for multiple-layer, low-emittance air spaces, and tests on actual constructions should be conducted to accurately determine thermal resistance values.

Values for foil insulation products supplied by manufacturers must also be used with caution because they apply only to systems that are identical to the configuration in which the product was tested. In addition, surface oxidation, dust accumulation, condensation, and other factors that change the condition of the low-emittance surface can reduce the thermal effectiveness of these insulation systems (Moroz 1951, Hooper and Moroz 1952). Deterioration results from contact with several types of solutions, either acidic or basic (*e.g.*, wet cement mortar or the preservatives found in decay-resistant lumber). Polluted environments may cause rapid and severe material degradation. However, site inspections show a predominance of well-preserved installations and only a small number of cases in which rapid and severe deterioration has occurred. An extensive review of the reflective building insulation system performance literature is provided by Goss and Miller (1989).

Table 3 Emittance Values of Various Surfaces and Effective Emittances of Air Spaces[a]

		Effective Emittance ϵ_{eff} of Air Space	
Surface	Average Emittance ϵ	One Surface Emittance ϵ; Other, 0.9	Both Surfaces Emittance ϵ
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (> 0.7gr/ft^2)	0.30[b]	0.29	—
Aluminum foil, with condensate clearly visible (> 2.9 gr/ft^2)	0.70[b]	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galvanized, bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

[a]These values apply in the 4 to 40 μm range of the electromagnetic spectrum.
[b]Values are based on data presented by Bassett and Trethowen (1984).

CALCULATING OVERALL THERMAL RESISTANCES

Relatively small conductive elements within an insulating layer or thermal bridges can substantially reduce the average thermal resistance of a component. Examples include wood and metal studs in frame walls, concrete webs in concrete masonry walls, and metal ties or other elements in insulated wall panels. The following examples illustrate how to calculate R-values and U-factors for components containing thermal bridges.

The following conditions are assumed in calculating the design R-values:

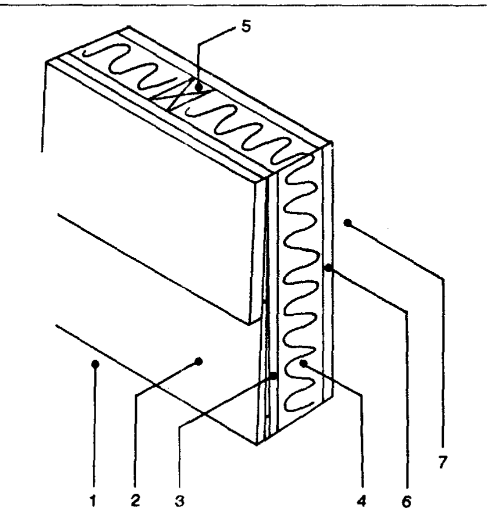
- Equilibrium or steady-state heat transfer, disregarding effects of heat storage
- Surrounding surfaces at ambient air temperature
- Exterior wind velocity of 15 mph for winter (surface with R = 0.17 °F·ft^2·h/Btu) and 7.5 mph for summer (surface with R = 0.25 °F·ft^2·h/Btu)
- Surface emittance of ordinary building materials is 0.90

Wood Frame Walls

The average overall R-values and U-factors of wood frame walls can be calculated by assuming either parallel heat flow paths through areas with different thermal resistances or isothermal planes. Equations (1) through (5) from Chapter 20 are used.

For stud walls 16 in. on center (OC), the fraction of insulated cavity is about 0.75; the fraction of studs, plates, and sills is 0.21; and the fraction of headers is 0.04. For studs 24 in. OC, the respective values are 0.78, 0.18, and 0.04. These fractions contain an allowance for multiple studs, plates, sills, extra framing around windows, headers, and band joists.

Example 1A. Calculate the U-factor of the 2 by 4 stud wall shown in Figure 2. The studs are at 16 in. OC. There is 3.5-in. mineral fiber batt insulation (R-13) in the stud space. The inside finish is 0.5-in. gypsum wallboard; the outside is finished with rigid foam insulating sheathing (R-4) and 0.5-in. by 8-in. wood bevel lapped siding. The insulated cavity occupies approxi-



1. Outside surface
2. Wood bevel lapped siding
3. Sheathing (rigid foam insulation, Example 1A; wood fiberboard, Example 1B)
4. Mineral fiber batt insulation
5. Wood stud (nominal 2×4, Example 1A; nominal 2×6, Example 1B)
6. Gypsum wallboard
7. Inside surface

Fig. 2 Insulated Wood Frame Wall (Examples 1A and B)

mately 75% of the transmission area; the studs, plates, and sills occupy 21%; and the headers occupy 4%.

Solution: Obtain the R-values of the various building elements from Tables 1 and 4. Assume the R-value of the wood framing is R-1.25 per inch. Also, assume the headers are solid wood, in this case, and group them with the studs, plates, and sills.

Element	*R* (Insulated Cavity)	*R* (Studs, Plates, and Headers)
1. Outside surface, 15 mph wind	0.17	0.17
2. Wood bevel lapped siding	0.81	0.81
3. Rigid foam insulating sheathing	4.0	4.0
4. Mineral fiber batt insulation, 3.5 in.	13.0	—
5. Wood stud, nominal 2 × 4	—	4.38
6. Gypsum wallboard, 0.5 in.	0.45	0.45
7. Inside surface, still air	0.68	0.68
	$R_1 = 19.11$	$R_2 = 10.49$

Since the U-factor is the reciprocal of R-value, $U_1 = 0.052$ and $U_2 = 0.095$ Btu/·h·ft^2·°F.

If the wood framing (thermal bridging) is not included, Equation (3) from Chapter 20 may be used to calculate the U-factor of the wall as follows:

$$U_{av} = U_1 = 1/R_1 = 0.052 \text{ Btu/h}\cdot\text{ft}^2\cdot°\text{F}$$

If the wood framing is accounted for using the parallel flow method, the U-factor of the wall is determined using Equation (5) from Chapter 20 as follows:

$$U_{av} = (0.75 \times 0.052) + (0.25 \times 0.095) = 0.063 \text{ Btu/h}\cdot\text{ft}^2\cdot°\text{F}$$

If the wood framing is included using the isothermal planes method, the U-factor of the wall is determined using Equations (2) and (3) from Chapter 20 as follows:

$$R_{T(av)} = 4.98 + 1/[(0.75/13.0) + (0.25/4.38)] + 1.13$$
$$= 14.82\,°\text{F}\cdot\text{ft}^2\cdot\text{h/Btu}$$
$$U_{av} = 0.067 \text{ Btu/h}\cdot\text{ft}^2\cdot°\text{F}$$

For a frame wall with a 24-in. OC stud space, the average overall R-value becomes 15.18 °F·ft^2·h/Btu. Similar calculation procedures can be used to evaluate other wall designs.

Example 1B. Calculate the U-factor of a 2 by 6 stud wall, similar to the one considered in Example IA, except that the sheathing is 0.5-in. wood fiberboard and the studs are at 24 in. OC. There is 5.5-in. mineral fiber batt insulation (R-21) in the stud space. Assume the headers are double 2 by 8 framing (with a 0.5-in. air space), with a 2.0-in. air space between the headers and the wallboard.

Solution: Obtain the R-values of the various building elements from Tables 1 and 4. Assume the R-value of the wood framing is 1.25 per inch. In this case, the headers must be treated separately.

Element	*R* (Insulated Cavity)	*R* (Studs and Plates)	*R* (Headers)
1. Outside surface, 15 mph wind	0.17	0.17	0.17
2. Wood bevel lapped siding	0.81	0.81	0.81
3. Wood fiberboard sheathing, 0.5 in.	1.32	1.32	1.32
4. Mineral fiber batt insulation, 5.5 in.	21.0	—	—
5. Wood stud, nominal 2 × 6	—	6.88	—
6. Wood headers, double 2 × 8	—	—	3.75
7. Air space, 0.5 in.	—	—	0.90
8. Air space, 2 in.	—	—	0.90
9. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45
10. Inside surface, still air	0.68	0.68	0.68
	$R_1 = 24.43$	$R_2 = 10.31$	$R_3 = 8.98$

Since U-factor is the reciprocal of R-value, $U_1 = 0.041$, $U_2 = 0.097$, and $U_3 = 0.111$ Btu/h·ft^2·°F.

If the wood framing is accounted for using the parallel flow method, the U-factor of the wall is determined using Equation (5) from Chapter 20 as follows:

$$U_{av} = (0.78 \times 0.041) + (0.18 \times 0.097) + (0.04 \times 0.111)$$
$$= 0.054 \text{ Btu}\cdot\text{h}\cdot\text{ft}^2\cdot°\text{F}$$

If the wood framing is included using the isothermal planes method, the U-factor of the wall is determined using Equations (2) and (3) from Chapter 20 as follows:

$$R_{T(av)} = 2.30 + 1/[(0.78/21.0) + (0.18/6.88) + (0.04/5.55)] + 1.13$$
$$= 17.61\,°\text{F}\cdot\text{ft}^2\cdot\text{h/Btu}$$
$$U_{av} = 0.057 \text{ Btu/h}\cdot\text{ft}^2\cdot°\text{F}$$

If the headers are insulated with R-10 insulation, the average overall R-value becomes 18.57 °F·ft^2·h/Btu.

For a frame wall with a 16-in. OC stud space and uninsulated headers, the average overall R-value becomes 17.05 °F·ft^2·h/Btu. If the headers are insulated with R-10 insulation, the average overall R-value becomes 17.93 °F·ft^2·h/Btu. Similar calculation procedures can be used to evaluate other wall designs.

Masonry Walls

The average overall R-values of masonry walls can be estimated by assuming a combination of layers in series, one or more of which provides parallel paths. This method is used because heat flows laterally through block face shells so that transverse isothermal planes result. Average total resistance $R_{T(av)}$ is the sum of the resistances of the layers between such planes, each layer calculated as shown in Example 2.

Example 2. Calculate the overall thermal resistance and average U-factor of the 7-5/8-in. thick insulated concrete block wall shown in Figure 3. The two-core block has an average web thickness of 1-in. and a face shell thickness of 1-1/4-in. Overall block dimensions are 7-5/8 by 7-5/8 by 15-5/8 in. Measured thermal resistances of 112 lb/ft^3 concrete and 7 lb/ft^3 expanded perlite insulation are 0.10 and 2.90 °F·ft^2·h/Btu per inch, respectively.

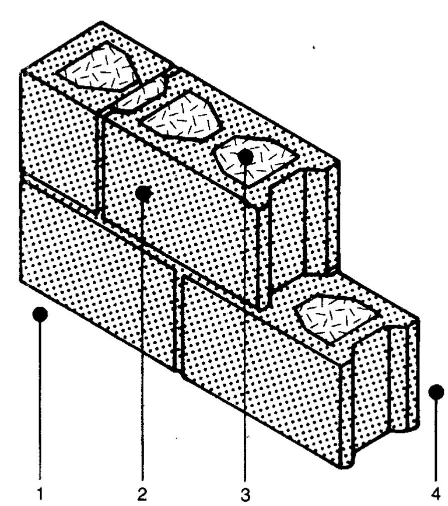


Fig. 3 Insulated Concrete Block Wall (Example 2)

Solution: The equation used to determine the overall thermal resistance of the insulated concrete block wall is derived from Equations (2) and (5) from Chapter 20 and is given below:

$$R_{T(av)} = R_i + R_f + \left(\frac{a_w}{R_w} + \frac{a_c}{R_c}\right)^{-1} + R_o$$

where

$R_{T(av)}$ = overall thermal resistance based on assumption of isothermal planes
R_i = thermal resistance of inside air surface film (still air)
R_o = thermal resistance of outside air surface film (15 mph wind)
R_f = total thermal resistance of face shells
R_c = thermal resistance of cores between face shells
R_w = thermal resistance of webs between face shells
a_w = fraction of total area transverse to heat flow represented by webs of blocks
a_c = fraction of total area transverse to heat flow represented by cores of blocks

From the information given and the data in Table 1, determine the values needed to compute the overall thermal resistance.

R_i = 0.68
R_o = 0.17
R_f = (2)(1.25)(0.10) = 0.25
R_c = (5.125)(2.90) = 14.86
R_w = (5.125)(0.10) = 0.51
a_w = 3/15.625 = 0.192
a_c = 12.625/15.625 = 0.808

Using the equation given, the overall thermal resistance and average U-factor are calculated as follows:

$$R_{T(av)} = 0.68 + 0.25 + (0.51)(14.86)/[(0.808)(0.51) + (0.192)(14.86)] + 0.17$$
$$= 0.68 + 0.25 + 2.33 + 0.17 = 3.43\,°F \cdot ft^2 \cdot h/Btu$$
$$U_{av} = 1/3.43 = 0.29\ Btu/h \cdot ft^2 \cdot °F$$

Based on guarded hot box tests of this wall without mortar joints, Tye and Spinney (1980) measured the average R-value for this insulated concrete block wall as 3.13 °F · ft² · h/Btu.

Assuming parallel heat flow only, the calculated resistance is usually higher than that calculated on the assumption of isothermal planes. The actual resistance generally is some value between the two calculated values. In the absence of test values, examination of the construction usually reveals whether a value closer to the higher or lower calculated R-value should be used. Generally, if the construction contains a layer in which lateral conduction is high compared with transmittance through the construction, the calculation with isothermal planes should be used. If the construction has no layer of high lateral conductance, the parallel heat flow calculation should be used.

Hot box tests of insulated and uninsulated masonry walls constructed with block of conventional configuration show that thermal resistances calculated using the isothermal planes heat flow method agree well with measured values (Van Geem 1985, Valore 1980, Shu *et al.* 1979). Neglecting horizontal mortar joints in conventional block can result in thermal transmittance values up to 16% lower than actual, depending on the density and thermal properties of the masonry, and 1 to 6% lower, depending on the core insulation material (Van Geem 1985, McIntyre 1984). For aerated concrete block walls, other solid masonry, and multicore block walls with full mortar joints, neglecting mortar joints can cause errors in R-values up to 40% (Valore 1988). Horizontal mortar joints usually found in concrete block wall construction are neglected in Example 2.

Panels Containing Metal

Curtain wall constructions often include metallic and other thermal bridges. The thermal resistance of panels can be significantly reduced by metallic thermal bridges. However, the capacity of the adjacent facing materials to transmit heat transversely to the metal is limited, and some contact resistance between all materials in contact limits the reduction. Contact resistances in building structures are only 0.06 to 0.6 °F · ft² · h/Btu—too small to be of concern in many cases. However, the contact resistances of steel framing members are important. Also, in many cases (as illustrated in Example 3), the area of metal in contact with the facing greatly exceeds the thickness of the metal which mitigates the influence.

Thermal characteristics for panels of sandwich construction can be computed by combining the thermal resistances of the various layers. However, few panels are true sandwich constructions; many have ribs and stiffeners that create complicated heat flow paths. R-values for the assembled sections should be determined on a representative sample by using a hot box method. If the sample is a wall section with air cavities on both sides of fibrous insulation, the sample must be of representative height since convective airflow can contribute significantly to heat flow through the test section. Computer modeling can also be useful, but all heat transfer mechanisms must be considered.

In Example 3, the metal member is only 0.020 in. thick, but it is in contact with adjacent facings over a 1.25 in.-wide area. The steel member is 3.50 in. deep, has a thermal resistance of approximately 0.011 °F · ft² · h/Btu, and is virtually isothermal. The calculation involves careful selection of the appropriate thickness for the steel member. If the member is assumed to be 0.020 in. thick, the fact that the flange transmits heat to the adjacent facing is ignored, and the heat flow through the steel is underestimated. If the member is assumed to be 1.25 in. thick, the heat flow through the steel is overestimated. In Example 3, the steel member behaves in much the same way as a rectangular member 1.25 in. thick and 3.50 in. deep with a thermal resistance of 0.69 °F · ft² · h/Btu [(1.25/0.020) × 0.011] does. The Building Research Association of New Zealand (BRANZ) commonly uses this approximation.

Example 3. Calculate the C-factor of the insulated steel frame wall shown in Figure 4. Assume that the steel member has an R-value of 0.69 °F · ft² · h/Btu and that the framing behaves as though it occupies approximately 8% of the transmission area.

Solution: Obtain the R-values of the various building elements from Table 4.

Element	*R* (Insul.)	*R* (Framing)
1. 0.5-in. gypsum wallboard	0.45	0.45
2. 3.5-in. mineral fiber batt insulation	11	—
3. Steel framing member	—	0.69
4. 0.5-in. gypsum wallboard	0.45	0.45
	R_1 = 11.90	R_2 = 1.59

Therefore, C_1 = 0.084; C_2 = 0.629 Btu/h · ft² °F.

If the steel framing (thermal bridging) is not considered, the C-factor of the wall is calculated using Equation (3) from Chapter 20 as follows:

$$C_{av} = C_1 = 1/R_1 = 0.084\ Btu/h \cdot ft^2 \cdot °F$$

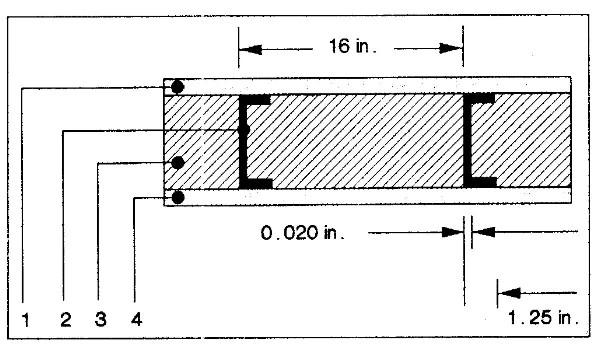


Fig. 4 Insulated Steel Frame Wall (Example 3)

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a]

Description	Density, lb/ft³	Conductivity[b] (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Resistance[c] (R): Per Inch Thickness (1/k), °F·ft²·h / Btu·in	Resistance[c] (R): For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
BUILDING BOARD						
Asbestos-cement board	120	4.0	—	0.25	—	0.24
Asbestos-cement board ... 0.125 in.	120	—	33.00	—	0.03	
Asbestos-cement board ... 0.25 in.	120	—	16.50	—	0.06	
Gypsum or plaster board ... 0.375 in.	50	—	3.10	—	0.32	0.26
Gypsum or plaster board ... 0.5 in.	50	—	2.22	—	0.45	
Gypsum or plaster board ... 0.625 in.	50	—	1.78	—	0.56	
Plywood (Douglas Fir)[d]	34	0.80	—	1.25	—	0.29
Plywood (Douglas Fir) ... 0.25 in.	34	—	3.20	—	0.31	
Plywood (Douglas Fir) ... 0.375 in.	34	—	2.13	—	0.47	
Plywood (Douglas Fir) ... 0.5 in.	34	—	1.60	—	0.62	
Plywood (Douglas Fir) ... 0.625 in.	34	—	1.29	—	0.77	
Plywood or wood panels ... 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable fiber board						
Sheathing, regular density[e] ... 0.5 in.	18	—	0.76	—	1.32	0.31
... 0.78125 in.	18	—	0.49	—	2.06	
Sheathing intermediate density[e] ... 0.5 in.	22	—	0.92	—	1.09	0.31
Nail-base sheathing[e] ... 0.5 in.	25	—	0.94	—	1.06	0.31
Shingle backer ... 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer ... 0.3125 in.	18	—	1.28	—	0.78	
Sound deadening board ... 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels, plain or acoustic	18	0.40	—	2.50	—	0.14
... 0.5 in.	18	—	0.80	—	1.25	
... 0.75 in.	18	—	0.53	—	1.89	
Laminated paperboard	30	0.50	—	2.00	—	0.33
Homogeneous board from repulped paper	30	0.50	—	2.00	—	0.28
Hardboard[e]						
Medium density	50	0.73	—	1.37	—	0.31
High density, service-tempered grade and service grade	55	0.82	—	1.22	—	0.32
High density, standard-tempered grade	63	1.00	—	1.00	—	0.32
Particleboard[e]						
Low density	37	0.71	—	1.41	—	0.31
Medium density	50	0.94	—	1.06	—	0.31
High density	62.5	1.18	—	0.85	—	0.31
Underlayment ... 0.625 in.	40	—	1.22	—	0.82	0.29
Waferboard	37	0.63	—	1.59	—	—
Wood subfloor ... 0.75 in.	—	—	1.06	—	0.94	0.33
BUILDING MEMBRANE						
Vapor—permeable felt	—	—	16.70	—	0.06	
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12	
Vapor—seal, plastic film	—	—	—	—	Negl.	
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	—	—	0.48	—	2.08	0.34
Carpet and rubber pad	—	—	0.81	—	1.23	0.33
Cork tile ... 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo ... 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05	0.30
vinyl asbestos						0.24
ceramic						0.19
Wood, hardwood finish ... 0.75 in.	—	—	1.47	—	0.68	
INSULATING MATERIALS						
Blanket and Batt[f,g]						
Mineral fiber, fibrous form processed from rock, slag, or glass						
approx. 3–4 in.	0.4–2.0	—	0.091	—	11	
approx. 3.5 in.	0.4–2.0	—	0.077	—	13	
approx. 3.5 in.	1.2–1.6	—	0.067	—	15	
approx. 5.5–6.5 in.	0.4–2.0	—	0.053	—	19	
approx. 5.5 in.	0.6–1.0	—	0.048	—	21	
approx. 6–7.5 in.	0.4–2.0	—	0.045	—	22	
approx. 8.25–10 in.	0.4–2.0	—	0.033	—	30	
approx. 10–13 in.	0.4–2.0	—	0.026	—	38	
Board and Slabs						
Cellular glass	8.0	0.33	—	3.03	—	0.18
Glass fiber, organic bonded	4.0–9.0	0.25	—	4.00	—	0.23
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—	0.30
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp.)	1.8–3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142b exp.)[h]	1.8–3.5	0.20	—	5.00	—	0.29

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a] (*Continued*)

Description	Density, lb/ft³	Conductivity[b] (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Resistance[c] (R): Per Inch Thickness (1/k), °F·ft²·h / Btu·in	Resistance[c] (R): For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—	—
	1.25	0.25	—	4.00	—	—
	1.5	0.24	—	4.17	—	—
	1.75	0.24	—	4.17	—	—
	2.0	0.23	—	4.35	—	—
Cellular polyurethane/polyisocyanurate[i] (CFC-11 exp.) (unfaced)	1.5	0.16–0.18	—	6.25–5.56	—	0.38
Cellular polyisocyanurate[i] (CFC-11 exp.)(gas-permeable facers)	1.5–2.5	0.16–0.18	—	6.25–5.56	—	0.22
Cellular polyisocyanurate[j] (CFC-11 exp.)(gas-impermeable facers)	2.0	0.14	—	7.04	—	0.22
Cellular phenolic (closed cell)(CFC-11, CFC-113 exp.)	3.0	0.12	—	8.20	—	—
Cellular phenolic (open cell)	1.8–2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16–17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Acoustical tile	21.0	0.37	—	2.70	—	—
Mineral fiberboard, wet molded						
Acoustical tile[k]	23.0	0.42	—	2.38	—	0.14
Wood or cane fiberboard						
Acoustical tile,[k] 0.5 in.	—	—	0.80	—	1.25	0.31
Acoustical tile[k] 0.75 in.	—	—	0.53	—	1.89	—
Interior finish (plank, tile)	15.0	0.35	—	2.86	—	0.32
Cement fiber slabs (shredded wood with Portland cement binder)	25–27.0	0.50–0.53	—	2.0–1.89	—	—
Cement fiber slabs (shredded wood with magnesia oxysulfide binder)	22.0	0.57	—	1.75	—	0.31
Loose Fill						
Cellulosic insulation (milled paper or wood pulp)	2.3–3.2	0.27–0.32	—	3.70–3.13	—	0.33
Perlite, expanded	2.0–4.1	0.27–0.31	—	3.7–3.3	—	0.26
	4.1–7.4	0.31–0.36	—	3.3–2.8	—	—
	7.4–11.0	0.36–0.42	—	2.8–2.4	—	—
Mineral fiber (rock, slag, or glass)[g]						
approx. 3.75–5 in.	0.6–2.0	—	—	—	11.0	0.17
approx. 6.5–8.75 in.	0.6–2.0	—	—	—	19.0	—
approx. 7.5–10 in.	0.6–2.0	—	—	—	22.0	—
approx. 10.25–13.75 in.	0.6–2.0	—	—	—	30.0	—
Mineral fiber (rock, slag, or glass)[g]						
approx. 3.5 in. (closed sidewall application)	2.0–3.5	—	—	—	12.0–14.0	—
Vermiculite, exfoliated	7.0–8.2	0.47	—	2.13	—	0.32
	4.0–6.0	0.44	—	2.27	—	—
Spray Applied						
Polyurethane foam	1.5–2.5	0.16–0.18	—	6.25–5.56	—	—
Ureaformaldehyde foam	0.7–1.6	0.22–0.28	—	4.55–3.57	—	—
Cellulosic fiber	3.5–6.0	0.29–0.34	—	3.45–2.94	—	—
Glass fiber	3.5–4.5	0.26–0.27	—	3.85–3.70	—	—
METALS						
(See Chapter 36, Table 3)						
ROOFING						
Asbestos-cement shingles	120	—	4.76	—	0.21	0.24
Asphalt roll roofing	70	—	6.50	—	0.15	0.36
Asphalt shingles	70	—	2.27	—	0.44	0.30
Built-up roofing 0.375 in.	70	—	3.00	—	0.33	0.35
Slate 0.5 in.	—	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31
PLASTERING MATERIALS						
Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20
Sand aggregate 0.375 in.	—	—	13.3	—	0.08	0.20
Sand aggregate 0.75 in.	—	—	6.66	—	0.15	0.20
Gypsum plaster:						
Lightweight aggregate 0.5 in.	45	—	3.12	—	0.32	—
Lightweight aggregate 0.625 in.	45	—	2.67	—	0.39	—
Lightweight aggregate on metal lath 0.75 in.	—	—	2.13	—	0.47	—
Perlite aggregate	45	1.5	—	0.67	—	0.32
Sand aggregate	105	5.6	—	0.18	—	0.20
Sand aggregate 0.5 in.	105	—	11.10	—	0.09	—
Sand aggregate 0.625 in.	105	—	9.10	—	0.11	—
Sand aggregate on metal lath 0.75 in.	—	—	7.70	—	0.13	—
Vermiculite aggregate	45	1.7	—	0.59	—	—
MASONRY MATERIALS						
Masonry Units						
Brick, fired clay	150	8.4–10.2	—	0.12–0.10	—	—
	140	7.4–9.0	—	0.14–0.11	—	—
	130	6.4–7.8	—	0.16–0.12	—	—
	120	5.6–6.8	—	0.18–0.15	—	0.19
	110	4.9–5.9	—	0.20–0.17	—	—

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a] (*Continued*)

Description	Density, lb/ft³	Conductivity[b] (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Resistance[c] (R) Per Inch Thickness (1/k), °F·ft²·h / Btu·in	Resistance[c] (R) For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Brick, fired clay *continued*	100	4.2–5.1	—	0.24–0.20	—	—
	90	3.6–4.3	—	0.28–0.24	—	—
	80	3.0–3.7	—	0.33–0.27	—	—
	70	2.5–3.1	—	0.40–0.33	—	—
Clay tile, hollow						
1 cell deep 3 in.	—	—	1.25	—	0.80	0.21
1 cell deep 4 in.	—	—	0.90	—	1.11	—
2 cells deep 6 in.	—	—	0.66	—	1.52	—
2 cells deep 8 in.	—	—	0.54	—	1.85	—
2 cells deep 10 in.	—	—	0.45	—	2.22	—
3 cells deep 12 in.	—	—	0.40	—	2.50	—
Concrete blocks[i]						
Limestone aggregate						
8 in., 36 lb, 138 lb/ft³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.48	—	2.1	—
12 in., 55 lb, 138 lb/ft³ concrete, 2 cores	—	—	—	—	—	—
Same with perlite filled cores	—	—	0.27	—	3.7	—
Normal weight aggregate (sand and gravel)						
8 in., 33-36 lb, 126-136 lb/ft³ concrete, 2 or 3 cores	—	—	0.90–1.03	—	1.11–0.97	0.22
Same with perlite filled cores	—	—	0.50	—	2.0	—
Same with verm. filled cores	—	—	0.52–0.73	—	1.92–1.37	—
12 in., 50 lb, 125 lb/ft³ concrete, 2 cores	—	—	0.81	—	1.23	0.22
Medium weight aggregate (combinations of normal weight and lightweight aggregate)						
8 in., 26-29 lb, 97-112 lb/ft³ concrete, 2 or 3 cores	—	—	0.58–0.78	—	1.71–1.28	—
Same with perlite filled cores	—	—	0.27–0.44	—	3.7–2.3	—
Same with verm. filled cores	—	—	0.30	—	3.3	—
Same with molded EPS (beads) filled cores	—	—	0.32	—	3.2	—
Same with molded EPS inserts in cores	—	—	0.37	—	2.7	—
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
6 in., 16-17 lb 85-87 lb/ft³ concrete, 2 or 3 cores	—	—	0.52–0.61	—	1.93–1.65	—
Same with perlite filled cores	—	—	0.24	—	4.2	—
Same with verm. filled cores	—	—	0.33	—	3.0	—
8 in., 19-22 lb, 72-86 lb/ft³ concrete,	—	—	0.32–0.54	—	3.2–1.90	0.21
Same with perlite filled cores	—	—	0.15–0.23	—	6.8–4.4	—
Same with verm. filled cores	—	—	0.19–0.26	—	5.3–3.9	—
Same with molded EPS (beads) filled cores	—	—	0.21	—	4.8	—
Same with UF foam filled cores	—	—	0.22	—	4.5	—
Same with molded EPS inserts in cores	—	—	0.29	—	3.5	—
12 in., 32-36 lb, 80-90 lb/ft³ concrete, 2 or 3 cores	—	—	0.38–0.44	—	2.6–2.3	—
Same with perlite filled cores	—	—	0.11–0.16	—	9.2–6.3	—
Same with verm. filled cores	—	—	0.17	—	5.8	—
Stone, lime, or sand						
Quartzitic and sandstone	180	72	—	0.01	—	—
	160	43	—	0.02	—	—
	140	24	—	0.04	—	—
	120	13	—	0.08	—	0.19
Calcitic, dolomitic, limestone, marble, and granite	180	30	—	0.03	—	—
	160	22	—	0.05	—	—
	140	16	—	0.06	—	—
	120	11	—	0.09	—	0.19
	100	8	—	0.13	—	—
Gypsum partition tile						
3 by 12 by 30 in., solid	—	—	0.79	—	1.26	0.19
3 by 12 by 30 in., 4 cells	—	—	0.74	—	1.35	—
4 by 12 by 30 in., 3 cells	—	—	0.60	—	1.67	—
Concretes						
Sand and gravel or stone aggregate concretes (concretes with more than 50% quartz or quartzite sand have conductivities in the higher end of the range)	150	10.0–20.0	—	0.10–0.05	—	—
	140	9.0–18.0	—	0.11–0.06	—	0.19–0.24
	130	7.0–13.0	—	0.14–0.08	—	—
Limestone concretes	140	11.1	—	0.09	—	—
	120	7.9	—	0.13	—	—
	100	5.5	—	0.18	—	—
Gypsum-fiber concrete (87.5% gypsum, 12.5% wood chips)	51	1.66	—	0.60	—	0.21
Cement/lime, mortar, and stucco	120	9.7	—	0.10	—	—
	100	6.7	—	0.15	—	—
	80	4.5	—	0.22	—	—
Lightweight aggregate concretes						
Expanded shale, clay, or slate; expanded slags; cinders; pumice (with density up to 100 lb/ft³); and scoria (sanded concretes have conductivities in the higher end of the range)	120	6.4–9.1	—	0.16–0.11	—	—
	100	4.7–6.2	—	0.21–0.16	—	0.20
	80	3.3–4.1	—	0.30–0.24	—	0.20
	60	2.1–2.5	—	0.48–0.40	—	—
	40	1.3	—	0.78	—	—

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a] (*Concluded*)

Description	Density, lb/ft³	Conductivity[b] (*k*), Btu·in/h·ft²·°F	Conductance (*C*), Btu/h·ft²·°F	Resistance[c] (*R*) Per Inch Thickness (1/*k*), °F·ft²·h/Btu·in	For Thickness Listed (1/*C*), °F·ft²·h/Btu	Specific Heat, Btu/lb·°F
Perlite, vermiculite, and polystyrene beads	50	1.8–1.9	—	0.55–0.53	—	—
	40	1.4–1.5	—	0.71–0.67	—	0.15–0.23
	30	1.1	—	0.91	—	—
	20	0.8	—	1.25	—	—
Foam concretes	120	5.4	—	0.19	—	—
	100	4.1	—	0.24	—	—
	80	3.0	—	0.33	—	—
	70	2.5	—	0.40	—	—
Foam concretes and cellular concretes	60	2.1	—	0.48	—	—
	40	1.4	—	0.71	—	—
	20	0.8	—	1.25	—	—
SIDING MATERIALS (on flat surface)						
Shingles						
Asbestos-cement	120	—	4.75	—	0.21	—
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19	0.28
Wood, plus insul. backer board, 0.3125 in.	—	—	0.71	—	1.40	0.31
Siding						
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35
Hardboard siding, 0.4375 in.	—	—	1.49	—	0.67	0.28
Wood, drop, 1 by 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 by 8 in., lapped	—	—	1.23	—	0.81	0.28
Wood, bevel, 0.75 by 10 in., lapped	—	—	0.95	—	1.05	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.59	—	0.59	0.29
Aluminum or Steel[m], over sheathing						
Hollow-backed	—	—	1.61	—	0.61	0.29
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	1.82	0.32
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.96	—
Architectural (soda-lime float) glass	158	6.9	—	—	—	0.21
WOODS (12% moisture content)[e,n]						
Hardwoods						0.39[o]
Oak	41.2–46.8	1.12–1.25	—	0.89–0.80	—	
Birch	42.6–45.4	1.16–1.22	—	0.87–0.82	—	
Maple	39.8–44.0	1.09–1.19	—	0.92–0.84	—	
Ash	38.4–41.9	1.06–1.14	—	0.94–0.88	—	
Softwoods						0.39[o]
Southern Pine	35.6–41.2	1.00–1.12	—	1.00–0.89	—	
Douglas Fir-Larch	33.5–36.3	0.95–1.01	—	1.06–0.99	—	
Southern Cypress	31.4–32.1	0.90–0.92	—	1.11–1.09	—	
Hem-Fir, Spruce-Pine-Fir	24.5–31.4	0.74–0.90	—	1.35–1.11	—	
West Coast Woods, Cedars	21.7–31.4	0.68–0.90	—	1.48–1.11	—	
California Redwood	24.5–28.0	0.74–0.82	—	1.35–1.22	—	

[a]Values are for a mean temperature of 75°F. Representative values for dry materials are intended as design (not specification) values for materials in normal use. Thermal values of insulating materials may differ from design values depending on their in-situ properties (*e.g.*, density and moisture content, orientation, etc.) and variability experienced during manufacture. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.
[b]To obtain thermal conductivities in Btu/h·ft·°F, divide the *k*-factor by 12 in./ft.
[c]Resistance values are the reciprocals of *C* before rounding off *C* to two decimal places.
[d]Lewis (1967).
[e]U.S. Department of Agriculture (1974).
[f]Does not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an airspace, see Tables 2 and 3 for the insulating value of an airspace with the appropriate effective emittance and temperature conditions of the space.
[g]Conductivity varies with fiber diameter. (See Chapter 20, Factors Affecting Thermal Performance.) Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed in the table. Due to differences in manufacturing processes and materials, the product thicknesses, densities, and thermal conductivities vary over considerable ranges for a specified R-value.
[h]This material is relatively new and data are based on limited testing.
[i]For additional information, see Society of Plastics Engineers (SPI) *Bulletin* U108. Values are for aged, unfaced board stock. For change in conductivity with age of expanded polyurethane/polyisocyanurate, see Chapter 20, Factors Affecting Thermal Performance.
[j]Values are for aged products with gas-impermeable facers on the two major surfaces. An aluminum foil facer of 0.001 in. thickness or greater is generally considered impermeable to gases. For change in conductivity with age of expanded polyisocyanurate, see Chapter 20, Factors Affecting Thermal Performance, and SPI *Bulletin* U108.
[k]Insulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.
[l]Values for fully grouted block may be approximated using values for concrete with a similar unit weight.
[m]Values for metal siding applied over flat surfaces vary widely, depending on amount of ventilation of airspace beneath the siding; whether airspace is reflective of non-reflective; and on thickness, type, and application of insulating backing-board used. Values given are averages for use as design guides, and were obained from several guarded hot box tests (ASTM C236) or calibrated hot box (ASTM C976) on hollow-backed types and types made using backing-boards of wood fiber, foamed plastic, and glass fiber. Departures of ±50% or more from the values given may occur.
[n]See Adams (1971), MacLean (1941), and Wilkes (1979). The conductivity values listed are for heat transfer across the grain. The thermal conductivity of wood varies linearly with the density, and the density ranges listed are those normally found for the wood species given. If the density of the wood species is not known, use the mean conductivity value. For extrapolation to other moisture contents, the following empirical equation developed by Wilkes (1979) may be used:

$$k = 0.1791 + \frac{(1.874 \times 10^{-2} + 5.753 \times 10^{-4} M)\rho}{1 + 0.01M}$$

where ρ is density of the moist wood in lb/ft³, and M is the moisture content in percent.
[o]From Wilkes (1979), an empirical equation for the specific heat of moist wood at 75°F is as follows:

$$c_p = \frac{(0.299 + 0.01M)}{(1 + 0.01M)} + \Delta c_p$$

where Δc_p accounts for the heat of sorption and is denoted by

$$\Delta c_p = M(1.921 \times 10^{-3} - 3.168 \times 10^{-5} M)$$

where M is the moisture content in percent by mass.

If the steel framing is accounted for using the parallel flow method, the C-factor of the wall is determined using Equation (5) from Chapter 20 as follows:

$$C_{av} = (0.92 \times 0.084) + (0.08 \times 0.629) = 0.128 \text{ Btu/h}\cdot\text{ft}^2\cdot{}^\circ\text{F}$$
$$R_{T(av)} = 7.81\,{}^\circ\text{F}\cdot\text{ft}^2\cdot\text{h/Btu}$$

If the steel framing is included using the isothermal planes method, the C-factor of the wall is determined using Equations (2) and (3) from Chapter 20 as follows:

$$R_{T(av)} = 0.45 + 1/[(0.92/11.00) + (0.08/0.69)] + 0.45 = 5.91\,{}^\circ\text{F}\cdot\text{ft}^2\cdot\text{h/Btu}$$
$$C_{av} = 0.169 \text{ Btu/h}\cdot\text{ft}^2\cdot{}^\circ\text{F}$$

For this insulated steel frame wall, Farouk and Larson (1983) measured an average R-value of 6.61°F · ft² · h/Btu.

In ASHRAE/IES *Standard* 90.1-1989, Energy Efficient Design of New Buildings except New Low-Rise Residential Buildings, one method given for determining the thermal resistance of wall assemblies containing metal framing involves using a parallel path correction factor F_c. The F_c values are included in Table 8C-2 of ASHRAE/IES *Standard* 90.1-1989. For 2 by 4 steel framing, 16 in. on center, $F_c = 0.50$. Using the correction factor method, an R-value of 6.40 · °F · ft² · h/Btu [0.45 + 11(0.50) + 0.45] is obtained for the wall described in Example 3.

Zone Method of Calculation

For structures with widely spaced metal members of substantial cross-sectional area, calculation by the isothermal planes method can result in thermal resistance values that are too low. For these constructions, the *zone method* can be used. This method involves two separate computations—one for a chosen limited portion, Zone A, containing the highly conductive element; the other for the remaining portion of simpler construction, Zone B. The two computations are then combined using the parallel flow method, and the average transmittance per unit overall area is calculated. The basic laws of heat transfer are applied by adding the area conductances CA of elements in parallel, and adding area resistances R/A of elements in series.

The surface shape of Zone A is determined by the metal element. For a metal beam (see Figure 5), the Zone A surface is a strip of width W that is centered on the beam. For a rod perpendicular to panel surfaces, it is a circle of diameter W. The value of W is calculated from Equation (1), which is empirical. The value of d should not be less than 0.5 in. for still air.

$$W = m + 2d \quad (1)$$

where

m = width or diameter of metal heat path terminal, in.
d = distance from panel surface to metal, in.

Generally, the value of W should be calculated using Equation (1) for each end of the metal heat path; the larger value, within the limits of the basic area, should be used as illustrated in Example 4.

Example 4. Calculate transmittance of the roof deck shown in Figure 5. Tee-bars at 24 in. OC support glass fiber form boards, gypsum concrete, and built-up roofing. Conductivities of components are: steel, 314.4 Btu · in/h · ft² · °F; gypsum concrete, 1.66 Btu · in/h · ft² · °F; and glass fiber form board, 0.25 Btu · in/h · ft² · °F. Conductance of built-up roofing is 3.00 Btu/h · ft² · °F.

Solution: The basic area is 2 ft² (24 in. by 12 in.) with a tee-bar (12 in. long) across the middle. This area is divided into Zones A and B.

Zone A is determined from Equation (1) as follows:

$$\text{Top side } W = m + 2d = 0.625 + (2 \times 1.5) = 3.625 \text{ in.}$$
$$\text{Bottom side } W = m + 2d = 2.0 + (2 \times 0.5) = 3.0 \text{ in.}$$

Using the larger value of W, the area of Zone A is (12 × 3.625)/144 = 0.302 ft². The area of Zone B is 2.0 − 0.302 = 1.698 ft².

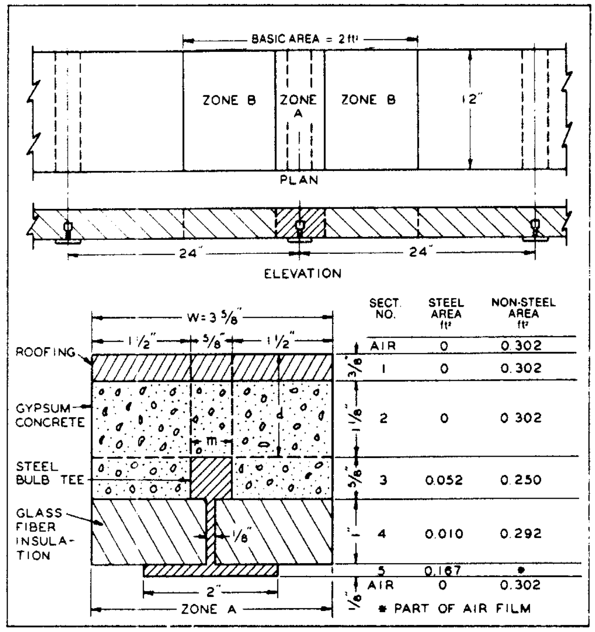


Fig. 5 Gypsum Roof Deck on Bulb Tees (Example 4)

To determine area transmittance for Zone A, divide the structure within the zone into five sections parallel to the top and bottom surfaces (Figure 5). The area conductance CA of each section is calculated by adding the area conductances of its metal and nonmetal paths. Area conductances of the sections are converted to area resistances R/A and added to obtain the total resistance of Zone A.

Section	Area × Conductance	= CA	$\frac{1}{CA} = \frac{R}{A}$
Air (outside, 15 mph)	0.302 × 6.00	1.81	0.55
No. 1, Roofing	0.302 × 3.00	0.906	1.10
No. 2, Gypsum concrete	0.302 × 1.66/1.125	0.446	2.24
No. 3, Steel	0.052 × 314.4/0.625	26.2	0.04
No. 3, Gypsum concrete	0.250 × 1.66/0.625	0.664	
No. 4, Steel	0.010 × 314.4/1.00	3.14	0.31
No. 4, Glass fiberboard	0.292 × 0.25/1.00	0.073	
No. 5, Steel	0.167 × 314.4/0.125	420.0	0.002
Air (inside)	0.302 × 1.63	0.492	2.03
		Total R/A	= 6.27

Area transmittance of Zone A = 1/(R/A) = 1/6.27 = 0.159.

For Zone B, the unit resistances are added and then converted to area transmittance, as shown in the following table.

Section	Resistance, R
Air (outside, 15 mph)	1/6.00 = 0.17
Roofing	1/3.00 = 0.33
Gypsum concrete	1.75/1.66 = 1.05
Glass fiberboard	1.00/0.25 = 4.00
Air (inside)	1/1.63 = 0.61
Total resistance	= 6.16

Since unit transmittance = $1/R$ = 0.162, the total area transmittance UA is calculated as follows:

Zone B = 1.698 × 0.162 = 0.275
Zone A = 0.159
Total area transmittance of basic area = 0.434
Transmittance per ft² = 0.434/2.0 = 0.217
Resistance per ft² = 4.61

Overall R-values of 4.57 and 4.85 °F · ft² · h/Btu have been measured in two guarded hot box tests of a similar construction.

When the steel member represents a relatively large proportion of the total heat flow path, as in Example 4, detailed calculations of resistance in sections 3, 4, and 5 of Zone A are unnecessary; if only the steel member is considered, the final result of Example 4 is the same. However, if the heat flow path represented by the steel member is small, as for a tie rod, detailed calculations for sections 3, 4, and 5 are necessary. A panel with an internal metallic structure and bonded on one or both sides to a metal skin or covering presents special problems of lateral heat flow not covered in the zone method.

Ceilings and Roofs

The overall R-value for ceilings of wood frame flat roofs can be calculated using Equations (1) through (5) from Chapter 20. Properties of the materials are found in Tables 1, 2, 3, and 4. The fraction of framing is assumed to be 0.10 for joists at 16 in. OC and 0.07 for joists at 24 in. OC. The calculation procedure is similar to that shown in Example 1. Note that if the ceiling contains plane air spaces (see Table 2), the resistance depends on the direction of heat flow, *i.e.*, whether the calculation is for a winter (heat flow up) or summer (heat flow down) condition.

For ceilings of pitched roofs under winter conditions, calculate the R-value of the ceiling using the procedure for flat roofs. The heat loss from these ceilings can be obtained using a calculated attic temperature (see Chapter 25). Table 5 can be used to determine the effective resistance of the attic space under summer conditions for varying conditions of ventilation air temperature, airflow direction and rates, ceiling resistance, roof or sol-air temperatures, and surface emittances (Joy 1958).

The R-value is the total resistance obtained by adding the ceiling and effective attic resistances. The applicable temperature difference is that difference between room air and sol-air temperatures or between room air and roof temperatures (see Table 5, footnote f). Table 5 can be used for pitched and flat residential roofs over attic spaces. When an attic has a floor, the ceiling resistance should account for the complete ceiling-floor construction.

Windows and Doors

The U-factors given in Table 5 of Chapter 27 are for vertical glazing (*e.g.*, windows, glass in exterior doors, glass doors, and skylights). The values were computed using procedures outlined in Chapter 27. The U-factors in Table 6 are for exterior wood and steel doors. The values given for wood doors were calculated, and those for steel doors were taken from hot box tests (Sabine *et al.* 1975, Yellott 1965) or from manufacturers' test reports. An outdoor surface conductance of 6.0 Btu/h · ft² · °F was used, and the indoor surface conductance was taken as 1.46 Btu/h · ft² · °F for vertical surfaces with horizontal heat flow. All values given are for exterior doors without glazing. If an exterior door contains glazing, the glazing should be analyzed as a window, as illustrated in Example 5.

Example 5. Determine the U-factor of a fixed wood frame residential window containing double insulating glass with 0.5-in. air space and metal spacer for winter conditions.

Solution: From Chapter 27, Table 5, the U-factor of the center of the glass portion only is 0.49 Btu/h · ft² · °F for glazing 1D6, double glazing, 0.5-in. air space. The wood frame of the window must also be

Table 5 Effective Thermal Resistance of Ventilated Attics[a] (Summer Condition)

PART A. NONREFLECTIVE SURFACES

Ventilation Air Temperature, °F	Sol-Air[f] Temperature, °F	No Ventilation[b] 0		Natural Ventilation 0.1[d]		Power Ventilation[c] 0.5		1.0		1.5	
		Ceiling Resistance R^e, °F · ft² · /Btu									
		10	20	10	20	10	20	10	20	10	20
	120	1.9	1.9	2.8	3.4	6.3	9.3	9.6	16	11	20
80	140	1.9	1.9	2.8	3.5	6.5	10	9.8	17	12	21
	160	1.9	1.9	2.8	3.6	6.7	11	10	18	13	22
	120	1.9	1.9	2.5	2.8	4.6	6.7	6.1	10	6.9	13
90	140	1.9	1.9	2.6	3.1	5.2	7.9	7.6	12	8.6	15
	160	1.9	1.9	2.7	3.4	5.8	9.0	8.5	14	10	17
	120	1.9	1.9	2.2	2.3	3.3	4.4	4.0	6.0	4.1	6.9
100	140	1.9	1.9	2.4	2.7	4.2	6.1	5.8	8.7	6.5	10
	160	1.9	1.9	2.6	3.2	5.0	7.6	7.2	11	8.3	13

PART B. REFLECTIVE SURFACES[g]

Ventilation Air Temperature, °F	Sol-Air[f] Temperature, °F	0: 10	0: 20	0.1: 10	0.1: 20	0.5: 10	0.5: 20	1.0: 10	1.0: 20	1.5: 10	1.5: 20
	120	6.5	6.5	8.1	8.8	13	17	17	25	19	30
80	140	6.5	6.5	8.2	9.0	14	18	18	26	20	31
	160	6.5	6.5	8.3	9.2	15	18	19	27	21	32
	120	6.5	6.5	7.5	8.0	10	13	12	17	13	19
90	140	6.5	6.5	7.7	8.3	12	15	14	20	16	22
	160	6.5	6.5	7.9	8.6	13	16	16	22	18	25
	120	6.5	6.5	7.0	7.4	8.0	10	8.5	12	8.8	12
100	140	6.5	6.5	7.3	7.8	10	12	11	15	12	16
	160	6.5	6.5	7.6	8.2	11	14	13	18	15	20

[a]Although the term effective resistance is commonly used when there is attic ventilation, this table includes values for situations with no ventilation. The effective resistance of the attic added to the resistance ($1/U$) of the ceiling yields the effective resistance of this combination based on sol-air (see Chapter 26) and room temperatures. These values apply to wood frame construction with a roof deck and roofing that has a conductance of 1.0 Btu/h · ft² · °F.

[b]This condition cannot be achieved in the field unless extreme measures are taken to tightly seal the attic.

[c]Based on air discharging outward from attic.

[d]When attic ventilation meets the requirements stated in Chapter 23, 0.1 cfm/ft² is assumed as the natural summer ventilation rate.

[e]When determining ceiling resistance, do not add the effect of a reflective surface facing the attic, as it is accounted for in Table 5, Part B.

[f]Roof surface temperature rather than sol-air temperature (see Chapter 26) can be used if 0.25 is subtracted from the attic resistance shown.

[g]Surfaces with effective emittance ϵ_{eff} = 0.05 between ceiling joists facing attic space.

Table 6 Transmission Coefficients U for Wood and Steel Doors, Btu/h·ft²·°F

Nominal Door Thickness, in.	Description	No Storm Door	Wood Storm Door[c]	Metal Storm Door[d]
Wood Doors[a,b]				
1-3/8	Panel door with 7/16-in. panels[e]	0.57	0.33	0.37
1-3/8	Hollow core flush door	0.47	0.30	0.32
1-3/8	Solid core flush door	0.39	0.26	0.28
1-3/4	Panel door with 7/16-in. panels[e]	0.54	0.32	0.36
1-3/4	Hollow core flush door	0.46	0.29	0.32
1-3/4	Panel door with 1-1/8-in. panels[e]	0.39	0.26	0.28
1-3/4	Solid core flush door	0.40	—	0.26
2-1/4	Solid core flush door	0.27	0.20	0.21
Steel Doors[b]				
1-3/4	Fiberglass or mineral wool core with steel stiffeners, no thermal break[f]	0.60	—	—
1-3/4	Paper honeycomb core without thermal break[f]	0.56	—	—
1-3/4	Solid urethane foam core without thermal break[a]	0.40	—	—
1-3/4	Solid fire rated mineral fiberboard core without thermal break[f]	0.38	—	—
1-3/4	Polystyrene core without thermal break (18 gage commercial steel)[f]	0.35	—	—
1-3/4	Polyurethane core without thermal break (18 gage commercial steel)[f]	0.29	—	—
1-3/4	Polyurethane core without thermal break (24 gage residential steel)[f]	0.29	—	—
1-3/4	Polyurethane core with thermal break and wood perimeter (24 gage residential steel)[f]	0.20	—	—
1-3/4	Solid urethane foam core with thermal break[a]	0.20	—	0.16

Note: All U-factors for exterior doors in this table are for doors with no glazing, except for the storm doors which are in addition to the main exterior door. Any glazing area in exterior doors should be included with the appropriate glass type and analyzed as a window (see Chapter 27). Interpolation and moderate extrapolation are permitted for door thicknesses other than those specified.
[a]Values are based on a nominal 32 by 80 in. door size with no glazing.
[b]Outside air conditions: 15 mph wind speed, 0°F air temperature; inside air conditions: natural convection, 70°F air temperature.
[c]Values for wood storm door are for approximately 50% glass area.
[d]Values for metal storm door are for any percent glass area.
[e]55% panel area.
[f]ASTM C 236 hotbox data on a nominal 3 by 7 ft door size with no glazing.

considered when determining the window U-factor. Referring to Table 5 in Chapter 27, for a fixed wood frame window with a 0.5-in. air space and metal spacer, the U-factor is given as 0.51 Btu/h·ft²·°F.

All R-values are approximate, since a significant portion of the resistance of a window or door is contained in the air film resistances, and some parameters that may have important effects are not considered. For example, the listed U-factors assume the surface temperatures of surrounding bodies are equal to the ambient air temperature. However, the indoor surface of a window or door in an actual installation may be exposed to nearby radiating surfaces, such as radiant heating panels, or opposite walls with much higher or lower temperatures than the indoor air. Air movement across the indoor surface of a window or door, such as that caused by nearby heating and cooling outlet grilles, increases the U-factor; and air movement (wind) across the outdoor surface of a window or door also increases the U-factor.

U_o Concept

In Section 4 of ASHRAE *Standard* 90A-1980, Energy Conservation in New Building Design, requirements are stated in terms of U_o, where U_o is the combined thermal transmittance of the respective areas of gross exterior wall, roof or ceiling or both, and floor assemblies. The U_o equation for a wall is as follows:

$$U_o = (U_{wall} A_{wall} + U_{window} A_{window} + U_{door} A_{door})/A_o \quad (2)$$

where

U_o = average thermal transmittance of gross wall area
A_o = gross area of exterior walls
U_{wall} = thermal transmittance of all elements of opaque wall area
A_{wall} = opaque wall area
U_{window} = thermal transmittance of window area (including frame)
A_{window} = window area (including frame)
U_{door} = thermal transmittance of door area
A_{door} = door area

Where more than one type of wall, window, or door is used, the UA term for that exposure should be expanded into its subelements, as shown in Equation (3).

$$\begin{aligned} U_oA_o = {} & U_{wall\,1}A_{wall\,1} + U_{wall\,2}A_{wall\,2} + \cdots + U_{wall\,m}A_{wall\,m} \\ & + U_{window\,1}A_{window\,1} + U_{window\,2}A_{window\,2} + \cdots \\ & + U_{window\,n}A_{window\,n} + U_{door\,1}A_{door\,1} \\ & + U_{door\,2}A_{door\,2} + \cdots + U_{door\,o}A_{door\,o} \end{aligned} \quad (3)$$

Example 6. Calculate U_o for a wall 30 ft by 8 ft, constructed as in Example 1A. The wall contains one window 60 in. by 34 in. and a second window 36 in. by 30 in. Both windows are constructed as in Example 5. The wall also contains a 1.75-in. solid core flush door with a metal storm door 34 in. by 80 in. (U = 0.26 Btu/h·ft²·°F from Table 6).

Solution: The U-factors for the wall and windows were obtained in Examples 1A and 5, respectively. The areas of the different components are:

$$A_{window} = [(60 \times 34) + (36 \times 30)]/144 = 21.7 \text{ ft}^2$$
$$A_{door} = (34 \times 80)/144 = 18.9 \text{ ft}^2$$
$$A_{wall} = (30 \times 8) - (21.7 + 18.9) = 199.4 \text{ ft}^2$$

Therefore, the combined thermal transmittance for the wall is:

$$U_o = \frac{(0.063 \times 199.4) + (0.51 \times 21.7) + (0.26 \times 18.9)}{(30 \times 8)}$$
$$= 0.119 \text{ Btu/h}\cdot\text{ft}^2\cdot{}^\circ\text{F}$$

Slab-on-Grade and Below-Grade Construction

Heat transfer through basement walls and floors to the ground depends on the following factors: (1) the difference between the air temperature within the room and that of the ground and outside air, (2) the material of the walls or floor, and (3) the thermal conductivity of the surrounding earth. The latter varies with local conditions and is usually unknown. Because of the great thermal inertia of the surrounding soil, ground temperature varies with depth, and there is a substantial time lag between changes in outdoor air temperatures and corresponding changes in ground temperatures. As a result, ground-coupled heat transfer is less amenable to steady-state representation than above-grade building elements. However, several simplified procedures for estimating ground-coupled heat transfer have been developed. These fall into two principal categories: (1) those that reduce the ground heat transfer problem to a closed form solution, and (2) those that use simple regression equations developed from statistically reduced multidimensional transient analyses.

Closed form solutions, including the ASHRAE arc-length procedure discussed in Chapter 25 by Latta and Boileau (1969), generally reduce the problem to one-dimensional, steady-state heat transfer. These procedures use simple, "effective" U-factors or ground temperatures or both. Methods differ in the various parameters averaged or manipulated to obtain these effective values. Closed form solutions provide acceptable results in climates that have a single dominant season, because the dominant season persists long enough to permit a reasonable approximation of steady-state conditions at shallow depths. The large errors (percentage) that are likely during transition seasons should not seriously affect building design decisions, since these heat flows are relatively insignificant when compared with those of the principal season.

The ASHRAE arc-length procedure is a reliable method for wall heat losses in cold winter climates. Chapter 25 discusses a slab-on-grade floor model developed by one study. Although both procedures give results comparable to transient computer solutions for cold climates, their results for warmer U.S. climates differ substantially.

Research conducted by Hougten *et al.* (1942) and Dill *et al.* (1945) indicates a heat flow of approximately 2.0 Btu/h · ft^2 through an uninsulated concrete basement floor with a temperature difference of 20 °F between the basement floor and the air 6 in. above it. A U-factor of 0.10 Btu/h · ft^2 · °F is sometimes used for concrete basement floors on the ground. For basement walls below grade, the temperature difference for winter design conditions is greater than for the floor. Test results indicate that at the midheight of the below-grade portion of the basement wall, the unit area heat loss is approximately twice that of the floor.

For concrete slab floors in contact with the ground at grade level, tests indicate that for small floor areas (equal to that of a 25 by 25 ft house) the heat loss can be calculated as proportional to the length of exposed edge rather than total area. This amounts

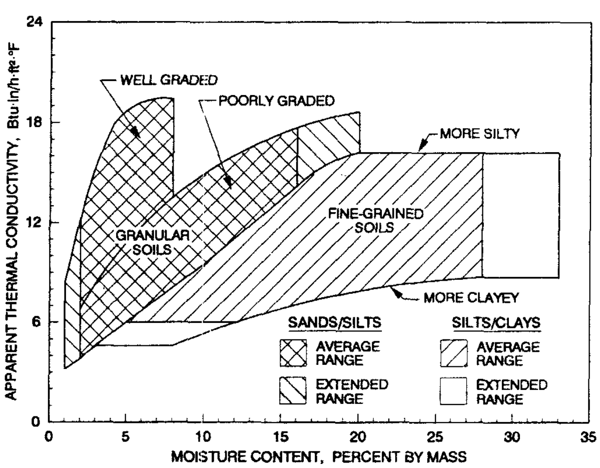


Fig. 6 Trends of Apparent Thermal Conductivity of Moist Soils

to 0.81 Btu/h per linear foot of exposed edge per °F difference between the indoor air temperature and the average outdoor air temperature. This value can be reduced appreciably by installing insulation under the ground slab and along the edge between the floor and abutting walls. In most calculations, if the perimeter loss is calculated accurately, no other floor losses need to be considered. Chapter 25 contains data for load calculations and heat loss values for below-grade walls and floors at different depths.

The second category of simplified procedures uses transient two-dimensional computer models to generate the ground heat transfer data that are then reduced to compact form by regression analysis (see Mitalas 1982 and 1983, Shipp 1983). These are the most accurate procedures available, but the database is very expensive to generate. In addition, these methods are limited to the range of climates and constructions specifically examined. Extrapolating beyond the outer bounds of the regression surfaces can produce significant errors.

Apparent Thermal Conductivity of Soil

Effective or apparent soil thermal conductivity is difficult to estimate precisely and may change substantially in the same soil at different times due to changed moisture conditions and the presence of freezing temperatures in the soil. Figure 6 shows the typical apparent soil thermal conductivity as a function of moisture content for different general types of soil. The figure is based on data presented in Salomone and Marlowe (1989) using envelopes of thermal behavior coupled with field moisture content ranges for different soil types. In Figure 6, the term well-graded applies to granular soils with good representation of all particle sizes from largest to smallest. The term poorly graded refers to granular soils with either a uniform gradation, in which most particles are about the same size, or a skip (or gap) gradation, in which particles of one or more intermediate sizes are not present.

Although thermal conductivity varies greatly over the complete range of possible moisture contents for a soil, this range can be narrowed if it is assumed that the moisture contents of most field soils lie between the "wilting point" of the soil (*i.e.*, the moisture content of a soil below which a plant cannot alleviate its wilting symptoms) and the "field capacity" of the soil (*i.e.*, the moisture

Table 7 Typical Apparent Thermal Conductivity Values for Soils, Btu · in/h · ft^2 · °F

		Recommended Values for Design[a]	
	Normal Range	Low[b]	High[c]
Sands	4.2 to 17.4	5.4	15.6
Silts	6 to 17.4	11.4	15.6
Clays	6 to 11.4	7.8	10.8
Loams	6 to 17.4	6.6	15.6

[a]Reasonable values for use when no site- or soil-specific data are available.
[b]Moderately conservative values for minimum heat loss through soil (*e.g.*, use in soil heat exchanger or earth-contact cooling calculations). Values are from Salomone and Marlowe (1989).
[c]Moderately conservative values for maximum heat loss through soil (*e.g.*, use in peak winter heat loss calculations). Values are from Salomone and Marlowe (1989).

Table 8 Typical Apparent Thermal Conductivity Values for Rocks, Btu · in/h · ft^2 · °F

	Normal Range
Pumice, tuff, obsidian	3.6 to 15.6
Basalt	3.6 to 18.0
Shale	6 to 27.6
Granite	12 to 30
Limestone, dolomite, marble	8.4 to 30
Quartzose sandstone	9.6 to 54

Table 9 Typical Water Vapor Permeance and Permeability Values for Common Building Materials[a]

Material	Thickness, in.	Permeance, Perm	Resistance[b], Rep	Permeability, Perm-in.	Resistance/in.[b], Rep/in.
Construction Materials					
Concrete (1:2:4 mix)				3.2	0.31
Brick masonry	4	0.8[f]	1.3		
Concrete block (cored, limestone aggregate)	8	2.4[f]	0.4		
Tile masonry, glazed	4	0.12[f]	8.3		
Asbestos cement board	0.12	4–8[d]	0.1–0.2		
With oil-base finishes		0.3–0.5[d]	2–3		
Plaster on metal lath	0.75	15[f]	0.067		
Plaster on wood lath		11[e]	0.091		
Plaster on plain gypsum lath (with studs)		20[f]	0.050		
Gypsum wall board (plain)	0.375	50[f]	0.020		
Gypsum sheathing (asphalt impregnated)	0.5			20[d]	0.050
Structural insulating board (sheathing quality)				20–50[f]	0.050–0.020
Structural insulating board (interior, uncoated)	0.5	50–90[f]	0.020–0.011		
Hardboard (standard)	0.125	11[f]	0.091		
Hardboard (tempered)	0.125	5[f]	0.2		
Built-up roofing (hot mopped)		0.0			
Wood, sugar pine				0.4–5.4[b]	2.5–0.19
Plywood (douglas fir, exterior glue)	0.25	0.7[f]	1.4		
Plywood (douglas fir, interior glue)	0.25	1.9[f]	0.53		
Acrylic, glass fiber reinforced sheet	0.056	0.12[d]	8.3		
Polyester, glass fiber reinforced sheet	0.048	0.05[d]	20		
Thermal Insulations					
Air (still)				120[f]	0.0083
Cellular glass				0.0[d]	∞
Corkboard				2.1–2.6[d]	0.48–0.38
				9.5[e]	0.11
Mineral wool (unprotected)				116[e]	0.0086
Expanded polyurethane (R-11 blown) board stock				0.4–1.6[d]	2.5–0.62
Expanded polystyrene—extruded				1.2[d]	0.83
Expanded polystyrene—bead				2.0–5.8[d]	0.50–0.17
Phenolic foam (covering removed)				26	0.038
Unicellular synthetic flexible rubber foam				0.02–0.15[d]	50–6.7
Plastic and Metal Foils and Films[c]					
Aluminum foil	0.001	0.0[d]	∞		
Aluminum foil	0.00035	0.05[d]	20		
Polyethylene	0.002	0.16[d]	6.3		3100
Polyethylene	0.004	0.08[d]	12.5		3100
Polyethylene	0.006	0.06[d]	17		3100
Polyethylene	0.008	0.04[d]	25		3100
Polyethylene	0.010	0.03[d]	33		3100
Polyvinylchloride, unplasticized	0.002	0.68[d]	1.5		
Polyvinylchloride, plasticized	0.004	0.8–1.4[d]	1.3–0.72		
Polyester	0.001	0.73[d]	1.4		
Polyester	0.0032	0.23[d]	4.3		
Polyester	0.0076	0.08[d]	12.5		
Cellulose acetate	0.01	4.6[d]	0.2		
Cellulose acetate	0.125	0.32[d]	3.1		

content of a soil that has been thoroughly wetted and then drained until the drainage rate has become negligibly small). After a prolonged dry spell, the moisture will be near the wilting point, and after a rainy period, the soil will have a moisture content near its field capacity. The moisture contents at these limits have been studied by many agricultural researchers, and data for different types of soil are given by Salomone and Marlowe (1989) and Kersten (1949). The shaded areas on Figure 6 approximate (1) the full range of moisture contents for different soil types and (2) a range between average values of each limit.

Table 7 gives a summary of design values for thermal conductivities of the basic soil classes. Table 8 gives ranges of thermal conductivity for some basic classes of rock. The value chosen depends on whether heat transfer is being calculated for minimum heat loss through the soil, as in a ground heat exchange system, or a maximum value, as in peak winter heat loss calculations for a basement. Hence, a high and a low value are given for each soil class.

As heat flows through the soil, the moisture tends to move away from the source of heat. This moisture migration provides initial mass transport of heat, but it also dries the soil adjacent to the heat source, hence lowering the apparent thermal conductivity in that zone of soil.

The following trends are typical in a soil when other factors are held constant:

1. k increases with moisture content
2. k increases with increasing dry density of a soil
3. k decreases with increasing organic content of a soil
4. k tends to decrease for soils with uniform gradations and rounded soil grains (because the grain-to-grain contacts are reduced)

Table 9 Typical Water Vapor Permeance and Permeability Values for Common Building Materials[a] (*Concluded*)

Material	Weight, lb/100 ft^2	Permeance, Perms			Resistance[h] Rep		
		Dry-Cup	Wet-Cup	Other	Dry-Cup	Wet-Cup	Other
Building Paper, Felts, Roofing Papers[g]							
Duplex sheet, asphalt laminated, aluminum foil one side	8.6	0.002	0.176		500	5.8	
Saturated and coated roll roofing	65	0.05	0.24		20	4.2	
Kraft paper and asphalt laminated, reinforced 30-120-30	6.8	0.3	1.8		3.3	0.55	
Blanket thermal insulation backup paper, asphalt coated	6.2	0.4	0.6–4.2		2.5	1.7–0.24	
Asphalt-saturated and coated vapor retarder paper	8.6	0.2–0.3	0.6		5.0–3.3	1.7	
Asphalt-saturated, but not coated, sheathing paper	4.4	3.3	20.2		0.3	0.05	
15-lb asphalt felt	14	1.0	5.6		1.0	0.18	
15-lb tar felt	14	4.0	18.2		0.25	0.055	
Single-kraft, double	3.2	31	42		0.032	0.024	
Liquid-Applied Coating Materials	**Thickness, in.**						
Commercial latex paints (dry film thickness)[i]							
Vapor retarder paint	0.0031			0.45			2.22
Primer-sealer	0.0012			6.28			0.16
Vinyl acetate/acrylic primer	0.002			7.42			0.13
Vinyl-acrylic primer	0.0016			8.62			0.12
Semi-gloss vinyl-acrylic enamel	0.0024			6.61			0.15
Exterior acrylic house and trim	0.0017			5.47			0.18
Paint-2 coats							
Asphalt paint on plywood			0.4			2.5	
Aluminum varnish on wood		0.3–0.5			3.3–2.0		
Enamels on smooth plaster				0.5–1.5			2.0–0.66
Primers and sealers on interior insulation board				0.9–2.1			1.1–0.48
Various primers plus 1 coat flat oil paint on plaster				1.6–3.0			0.63–0.33
Flat paint on interior insulation board				4			0.25
Water emulsion on interior insulation board				30–85			0.03–0.012
	Weight, oz/ft^2						
Paint-3 coats							
Exterior paint, white lead and oil on wood siding		0.3–1.0			3.3–1.0		
Exterior paint, white lead-zinc oxide and oil on wood		0.9			1.1		
Styrene-butadiene latex coating	2	11			0.09		
Polyvinyl acetate latex coating	4	5.5			0.18		
Chlorosulfonated polyethylene mastic	3.5	1.7			0.59		
	7.0	0.06			16		
Asphalt cutback mastic, 1/16 in., dry		0.14			7.2		
3/16 in., dry		0.0			—		
Hot melt asphalt	2	0.5			2		
	3.5	0.1			10		

[a]This table permits comparisons of materials; but in the selection of vapor retarder materials, exact values for permeance or permeability should be obtained from the manufacturer or from laboratory tests. The values shown indicate variations among mean values for materials that are similar but of different density, orientation, lot, or source. The values should not be used as design or specification data. Values from dry-cup and wet-cup methods were usually obtained from investigations using ASTM E96 and C355; values shown under others were obtained by two-temperature, special cell, and air velocity methods. Permeance, resistance, permeability, and resistance per unit thickness values are given in the following units:

Permeance	Perm	= gr/h · ft^2 · in. Hg
Resistance	Rep	= in. Hg · ft^2 · h/gr
Permeability	Perm-in.	= gr/h · ft^2 · (in. Hg/in.)
Resistance/unit thickness	Rep/in.	= (in. Hg · ft^2 · h/gr)/in.

[b]Depending on construction and direction of vapor flow.
[c]Usually installed as vapor retarders, although sometimes used as exterior finish and elsewhere near cold side, where special considerations are then required for warm side barrier effectiveness.
[d]Dry-cup method.
[e]Wet-cup method.
[f]Other than dry- or wet-cup method.
[g]Low permeance sheets used as vapor retarders. High permeance used elsewhere in construction.
[h]Resistance and resistance/in. values have been calculated as the reciprocal of the permeance and permeability values.
[i]Cast at 10 mils wet film thickness.

5. k of a frozen soil may be higher or lower than that of the same unfrozen soil (because the conductivity of ice is higher than that of water but lower than that of the typical soil grains). Differences in k below moisture contents of 7 to 8% are quite small. At approximately 15% moisture content, differences in k-factors may vary up to 30% from unfrozen values.

When calculating annual energy use, values that represent typical site conditions as they vary during the year should be chosen. In climates where ground freezing is significant, accurate heat transfer simulations should include the effect of the latent heat of fusion of water. The energy released during this phase change significantly retards the progress of the frost front in moist soils.

Water Vapor Transmission Data for Building Components

Table 9 gives typical water vapor permeance and permeability values for common building materials. These values can be used to calculate water vapor flow through building components and assemblies using Equations (14) through (17) in Chapter 20.

Table 10 Typical Thermal Conductivity k for Industrial Insulations at Various Mean Temperatures—Design Values[a]

Material	Max. Temp.,[b] °F	Typical Density, lb/ft³	Typical Conductivity k in Btu·in/h·ft²·°F at Mean Temp., °F													
			−100	−75	−50	−25	0	25	50	75	100	200	300	500	700	900
BLANKETS AND FELTS																
ALUMINOSILICATE FIBER																
7 to 10 μm diameter fiber	1800	4								0.24		0.32		0.54	0.99	1.03
	2000	6-8								0.25		0.30		0.48	0.78	0.95
3 μm diameter fiber	2200	4								0.22		0.29		0.45	0.59	0.74
MINERAL FIBER (Rock, slag, or glass)																
Blanket, metal reinforced	1200	6–12									0.26	0.32	0.39	0.54		
	1000	2.5–6									0.24	0.31	0.40	0.61		
Blanket, flexible, fine-fiber organic bonded	350	<0.75				0.25	0.26	0.28	0.30	0.33	0.36	0.53				
		0.75				0.24	0.25	0.27	0.29	0.32	0.34	0.48				
		1.0				0.23	0.24	0.25	0.27	0.29	0.32	0.43				
		1.5				0.21	0.22	0.23	0.25	0.27	0.28	0.37				
		2.0				0.20	0.21	0.22	0.23	0.25	0.26	0.33				
		3.0				0.19	0.20	0.21	0.22	0.23	0.24	0.31				
Blanket, flexible, textile fiber, organic bonded	350	0.65				0.27	0.28	0.29	0.30	0.31	0.32	0.50	0.68			
		0.75				0.26	0.27	0.28	0.29	0.31	0.32	0.48	0.66			
		1.0				0.24	0.25	0.26	0.27	0.29	0.31	0.45	0.60			
		1.5				0.22	0.23	0.24	0.25	0.27	0.29	0.39	0.51			
		3.0				0.20	0.21	0.22	0.23	0.24	0.25	0.32	0.41			
Felt, semirigid organic bonded	400	3–8						0.24	0.25	0.26	0.27	0.35	0.44			
	850	3	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.35	0.55			
Laminated and felted without binder	1200	7.5											0.35	0.45	0.60	
BLOCKS, BOARDS, AND PIPE INSULATION																
MAGNESIA	600	11–12									0.35	0.38	0.42			
85% CALCIUM SILICATE	1200	11–15									0.38	0.41	0.44	0.52	0.62	0.72
	1800	12–15												0.63	0.74	0.95
CELLULAR GLASS	900	7.8–8.2	0.24	0.25	0.26	0.28	0.29	0.30	0.32	0.33	0.34	0.41	0.49	0.70	1.01	
DIATOMACEOUS SILICA	1600	21–22												0.64	0.68	0.72
	1900	23–25												0.70	0.75	0.80
MINERAL FIBER (Glass)																
Organic bonded, block and boards	400	3–10	0.16	0.17	0.18	0.19	0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Nonpunking binder	1000	3–10									0.26	0.31	0.38	0.52		
Pipe insulation, slag, or glass	350	3–4					0.20	0.21	0.22	0.23	0.24	0.29				
	500	3–10					0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Inorganic bonded block	1000	10–15									0.33	0.38	0.45	0.55		
	1800	15–24									0.32	0.37	0.42	0.52	0.62	0.74
Pipe insulation, slag, or glass	1000	10–15									0.33	0.38	0.45	0.55		
Resin binder		15	0.23	0.24	0.25	0.26	0.28	0.29								
RIGID POLYSTYRENE																
Extruded (CFC-12 exp.) (smooth skin surface)	165	1.8–3.5	0.16	0.16	0.17	0.16	0.17	0.18	0.19	0.20						
Molded beads	165	1	0.17	0.19	0.20	0.21	0.22	0.24	0.25	0.26	0.28					
		1.25	0.17	0.18	0.19	0.20	0.22	0.23	0.24	0.25	0.27					
		1.5	0.16	0.17	0.19	0.20	0.21	0.22	0.23	0.24	0.26					
		1.75	0.16	0.17	0.18	0.19	0.20	0.22	0.23	0.24	0.25					
		2.0	0.15	0.16	0.18	0.19	0.20	0.21	0.22	0.23	0.24					
RIGID POLYURETHANE/POLYISOCYANURATE[c,d]																
Unfaced (CFC-11 exp.)	210	1.5–2.5	0.16	0.17	0.18	0.18	0.18	0.17	0.16	0.16	0.17					
RIGID POLYISOCYANURATE[e]																
Gas-impermeable facers (CFC-11 exp.)	250	2.0						0.12	0.13	0.14	0.15					
RIGID PHENOLIC																
Closed cell (CFC-11, CFC-113 exp.)		3.0						0.11	0.115	0.12	0.125					
RUBBER, Rigid foamed	150	4.5						0.20	0.21	0.22	0.23					
VEGETABLE AND ANIMAL FIBER																
Wool felt (pipe insulation)	180	20						0.28	0.30	0.31	0.33					
INSULATING CEMENTS																
MINERAL FIBER (Rock, slag, or glass)																
With colloidal clay binder	1800	24–30									0.49	0.55	0.61	0.73	0.85	
With hydraulic setting binder	1200	30–40									0.75	0.80	0.85	0.95		
LOOSE FILL																
Cellulose insulation (milled pulverized paper or wood pulp)		2.5–3							0.26	0.27	0.29					
Mineral fiber, slag, rock, or glass		2–5			0.19	0.21	0.23	0.25	0.26	0.28	0.31					
Perlite (expanded)		3–5	0.22	0.24	0.25	0.27	0.28	0.30	0.31	0.33	0.35					
Silica aerogel		7.6			0.13	0.14	0.15	0.15	0.16	0.17	0.18					
Vermiculite (expanded)		7–8.2			0.39	0.40	0.42	0.44	0.45	0.47	0.49					
		4–6			0.34	0.35	0.38	0.40	0.42	0.44	0.46					

[a]Representative values for dry materials, which are intended as design (not specification) values for materials in normal use. Insulation materials in actual service may have thermal values that vary from design values depending on their in-situ properties (*e.g.*, density and moisture content). For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

[b]These temperatures are generally accepted as maximum. When operating temperature approaches these limits, follow the manufacturers' recommendations.

[c]Some polyurethane foams are formed by means that produce a stable product (with respect to *k*), but most are blown with refrigerant and will change with time.

[d]See Table 4, footnote i.

[e]See Table 4, footnote j.

MECHANICAL AND INDUSTRIAL SYSTEMS

Thermal Transmission Data

Table 10 lists the thermal conductivities of various materials used as industrial insulations. These values are functions of the arithmetic mean of the temperatures of the inner and outer surfaces for each insulation.

Heat Loss from Pipes and Flat Surfaces

Tables 11A, 11B, and 12 give heat losses from bare steel pipes and flat surfaces and bare copper tubes. These tables were calculated using ASTM *Standard* C 680, Practice for Determination of Heat Gain or Loss and the Surface Temperature of Insulated Pipe and Equipment Systems by the Use of a Computer Program. User inputs for these programs include operating temperature, ambient temperature, pipe size, insulation type, number of insulation layers, and thickness for each layer. A program option allows the user to input a surface coefficient or surface emittance, surface orientation, and wind speed. The computer uses this information to calculate the heat flow and the surface temperature. The programs calculate the surface coefficients if the user has not already supplied them.

The equations used in ASTM C680 are:

$$h_{cv} = C\left(\frac{1}{d}\right)^{0.2}\left(\frac{1}{t_{avg}}\right)^{0.181}\Delta t^{0.266}\sqrt{1 + 1.277\,(\text{Wind})} \quad (4)$$

where

h_{cv} = convection surface coefficient, Btu/h · ft² · °F
d = diameter for cylinder, in. For flat surfaces and large cylinders ($d > 24$), use $d = 24$.
t_{avg} = average temperature of air film, °F
Δt = surface to air temperature difference, °F
Wind = air speed, mph
C = constant depending on shape and heat flow condition
= 1.016 for horizontal cylinders
= 1.235 for longer vertical cylinders
= 1.394 for vertical plates
= 1.79 for horizontal plates, warmer than air, facing upward
= 0.89 for horizontal plates, warmer than air, facing downward
= 0.89 for horizontal plates, cooler than air, facing upward
= 1.79 for horizontal plates, cooler than air, facing downward

$$h_{rad} = \frac{\epsilon \times 0.1713 \times 10^{-8}[(t_a + 459.6)^4 - (t_s + 459.6)^4]}{(t_a - t_s)} \quad (5)$$

where

h_{rad} = radiation surface coefficient, Btu/h · ft² · °F
ϵ = surface emittance
t_a = air temperature, °F
t_s = surface temperature, °F

Table 11A Heat Loss from Bare Steel Pipe to Still Air at 80 °F[a], Btu/h · ft

Nominal Pipe Size[b], in.	Pipe Inside Temperature, °F									
	180	280	380	480	580	680	780	880	980	1080
0.50	59.3	147.2	263.2	412.3	600.9	836.8	1128.6	1485.6	1918.0	2436.8
0.75	72.5	180.1	322.6	506.2	739.2	1031.2	1392.9	1836.0	2373.5	3018.8
1.00	88.8	220.8	396.1	622.7	910.9	1272.6	1721.2	2271.5	2939.4	3741.6
1.25	109.7	272.8	490.4	772.3	1131.7	1583.8	2145.6	2835.4	3673.4	4680.9
1.50	123.9	308.5	555.1	875.1	1283.8	1798.3	2438.2	3224.6	4180.5	5330.0
2.00	151.8	378.1	681.4	1076.3	1581.5	2218.9	3012.6	3989.2	5177.2	6606.8
2.50	180.5	450.0	811.9	1284.0	1888.8	2652.6	3604.3	4775.3	6199.5	7912.5
3.00	215.9	538.8	973.5	1541.8	2271.4	3194.0	4344.9	5762.2	7486.9	9562.3
3.50	243.9	609.0	1101.4	1746.1	2574.7	3623.6	4933.0	6546.4	8510.4	10874.3
4.00	271.6	678.6	1228.2	1948.7	2875.9	4050.5	5517.5	7326.0	9528.1	12178.9
4.50	299.2	747.7	1354.4	2150.9	3176.8	4477.7	6103.8	8109.5	10553.2	13496.2
5.00	329.8	824.7	1494.8	2375.4	3510.6	4950.7	6751.3	8972.5	11678.4	14936.3
6.00	387.1	968.7	1757.8	2796.8	4138.0	5841.4	7972.7	10603.1	13808.2	17667.6
7.00	440.5	1102.8	2003.0	3189.9	4723.9	6673.5	9114.2	12127.4	15799.4	20220.8
8.00	493.3	1235.7	2246.1	3580.0	5305.5	7500.0	10248.4	13642.2	17778.2	22758.0
9.00	545.9	1368.1	2488.8	3970.2	5888.7	8331.0	11392.1	15174.5	19787.1	25343.6
10.00	604.3	1514.8	2757.2	4400.7	6530.1	9241.1	12638.6	16835.1	21949.2	28104.9
11.00	656.0	1644.8	2995.5	4783.8	7102.1	10054.9	13756.2	18328.4	23900.3	30606.1
12.00	704.0	1762.3	3203.8	5104.9	7557.3	10661.8	14524.9	19256.7	24967.6	31766.8
14.00	771.0	1934.2	3525.9	5636.0	8373.9	11862.4	16235.5	21635.6	28212.3	36120.3
16.00	872.2	2189.0	3993.2	6387.4	9495.9	13458.0	18424.8	24556.6	32021.1	40990.7
18.00	972.5	2441.7	4456.7	7132.9	10609.4	15041.3	20596.7	27453.2	35795.6	45813.1
20.00	1072.1	2692.4	4916.8	7873.2	11715.1	16613.4	22752.5	30326.8	39537.6	50590.0
24.00	1269.3	3188.9	5828.3	9339.9	13905.5	19726.9	27019.7	36010.1	46930.3	60014.7

Table 11B Heat Loss from Flat Surfaces to Still Air at 80 °F, Btu/h · ft²

	Surface Inside Temperature, °F									
	180	280	380	480	580	680	780	880	980	1080
Vertical surface	212.2	533.1	973.3	1558.6	2321.2	3298.0	4530.1	6062.8	7945.5	10231.5
Horizontal surface										
Facing up	234.7	586.4	1061.1	1683.5	2484.9	3501.9	4775.4	6350.4	8276.3	10606.1
Facing down	183.6	465.3	861.4	1399.6	2112.8	3038.4	4217.8	5696.7	7524.5	9754.7

[a]Calculations from ASTM C680-82; steel: k = 314.4 Btu · in/h · ft² · °F; ϵ = 0.94.

[b]Losses per square foot of pipe for pipes larger than 24 in. can be considered the same as losses per square foot for 24-in. pipe.

Example 7. Compute total annual heat loss from 165 ft of nominal 2-in. bare steel pipe in service 4000 h per year. The pipe is carrying steam at 10 psi and is exposed to an average air temperature of 80°F.

Solution: The pipe temperature is taken as the steam temperature, which is 239.4°F, obtained by interpolation from Steam Tables. By interpolation in Table 11A between 180°F and 280°F, heat loss from a 2-in. pipe is 285.3 Btu/h·ft. Total annual heat loss from the entire line is 285.3 Btu/h·ft × 165 ft × 4000 h = 188 million Btu.

In calculating heat flow, Equations (9) and (10) from Chapter 20 generally are used. For dimensions of standard pipe and fitting sizes, refer to the *Piping Handbook*. For insulation product dimensions, refer to ASTM *Standard* C 585, Recommended Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS) System, or to the insulation manufacturers' literature.

Examples 8 and 9 illustrate how Equations (9) and (10) from Chapter 20 can be used to determine heat loss from both flat and cylindrical surfaces. Figure 7 shows surface resistance as a function of heat transmission for both flat and cylindrical surfaces. The surface emittance is assumed to be 0.85 to 0.90 in still air at 80°F.

Example 8. Compute heat loss from a boiler wall if the interior insulation surface temperature is 1100°F and ambient still air temperature is 80°F. The wall is insulated with 4.5 in. of mineral fiber block and 0.5 in. of mineral fiber insulating and finishing cement.

Solution: Assume that the mean temperature of the mineral fiber block is 700°F, the mean temperature of the insulating cement is 200°F, and the surface resistance R_s is 0.60.

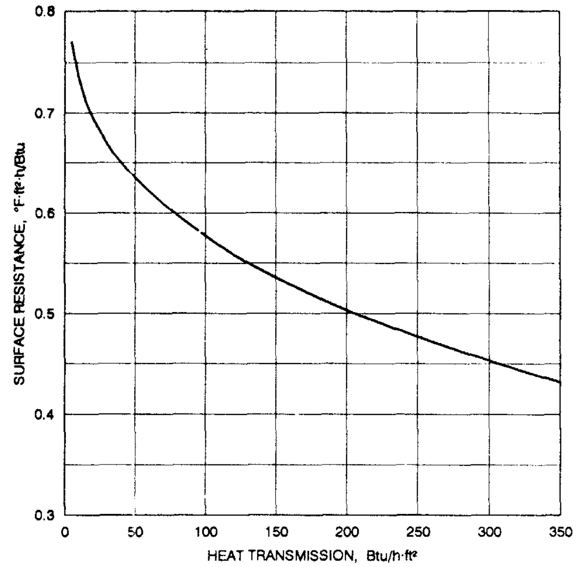


Fig. 7 Surface Resistance as Function of Heat Transmission for Flat Surfaces and Cylindrical Surfaces Greater than 24 Inches in Diameter

Table 12 Heat Loss from Bare Copper Tube to Still Air at 80°F[a], Btu/h·ft

Nominal Tube	Tube Inside Temperature, °F								
Size, in.	120	150	180	210	240	270	300	330	
0.250	7.1	14.1	21.9	30.6	39.9	49.9	60.6	71.9	
0.375	9.1	18.0	28.1	39.1	51.1	63.9	77.6	92.2	
0.500	11.0	21.8	34.0	47.4	61.9	77.5	94.1	111.8	
0.750	14.7	29.1	45.4	63.3	82.7	103.6	126.0	149.8	
1.000	18.3	36.2	56.4	78.7	102.8	128.9	156.7	186.5	
1.250	21.8	43.1	67.2	93.6	122.4	153.4	186.7	222.2	
1.500	25.2	49.8	77.6	108.3	141.5	177.4	216.0	257.1	
2.000	31.8	62.9	98.0	136.7	178.8	224.3	273.1	325.4	
2.500	38.3	75.6	117.9	164.4	215.1	269.8	328.7	391.8	Dull ϵ = 0.44
3.000	44.6	88.1	137.2	191.5	250.5	314.4	383.2	456.9	
3.500	50.8	100.3	156.3	218.0	285.4	358.2	436.7	520.8	
4.000	57.0	112.3	175.0	244.2	319.7	401.4	489.4	583.9	
5.000	69.0	135.9	211.7	295.5	386.9	486.0	592.8	707.6	
6.000	80.7	159.0	247.7	345.7	452.8	568.9	694.2	829.0	
8.000	103.7	204.1	317.8	443.7	581.3	730.7	892.1	1066.0	
10.000	126.1	247.9	386.1	539.1	706.5	888.4	1085.2	1297.4	
12.000	148.0	290.9	453.0	632.5	829.2	1043.1	1274.6	1524.4	
0.250	5.4	10.8	16.9	23.5	30.5	37.9	45.5	53.5	
0.375	6.8	13.7	21.4	29.7	38.6	47.9	57.6	67.6	
0.500	8.2	16.4	25.7	35.7	46.3	57.4	69.1	81.2	
0.750	10.7	21.6	33.8	46.9	60.9	75.6	90.9	106.8	
1.000	13.2	26.5	41.4	57.6	74.7	92.8	111.6	131.2	
1.250	15.5	31.3	48.8	67.8	88.0	109.3	131.6	154.7	
1.500	17.8	35.8	56.0	77.8	100.9	125.3	150.8	177.4	
2.000	22.2	44.6	69.7	96.8	125.7	156.1	187.9	221.1	
2.500	26.4	53.0	82.8	115.1	149.5	185.6	223.5	263.0	Bright ϵ = 0.08
3.000	30.5	61.2	95.6	132.8	172.4	214.2	257.9	303.5	
3.500	34.4	69.1	107.9	150.0	194.8	242.0	291.4	342.9	
4.000	38.3	76.8	120.0	166.8	216.6	269.1	324.1	381.4	
5.000	45.7	91.8	143.4	199.3	258.8	321.6	387.4	456.1	
6.000	53.0	106.3	166.0	230.7	299.7	372.5	448.7	528.3	
8.000	66.8	134.1	209.4	291.1	378.2	470.1	566.5	667.2	
10.000	80.2	160.8	251.0	349.0	453.4	563.7	679.5	800.4	
12.000	93.0	186.5	291.3	404.9	526.1	654.2	788.7	929.3	

[a]Calculations from ASTM C680-82; for copper: k = 2784 Btu·in/h·ft²·°F.

From Table 10, $k_1 = 0.62$ and $k_2 = 0.80$. Using Equation (9) from Chapter 20:

$$q_s = \frac{1100 - 80}{(4.5/0.62) + (0.5/0.80) + 0.60} = \frac{1020}{8.48}$$
$$= 120.2 \text{ Btu/h} \cdot \text{ft}^2$$

As a check, from Figure 7, at 120.2 Btu/h·ft², $R_s = 0.56$. The mean temperature of the mineral fiber block is:

$$4.5/0.62 = 7.26;\ 7.26/2 = 3.63$$
$$1100 - [(3.63/8.48)(1020)] = 1100 - 437 = 663\,°\text{F}$$

and the mean temperature of the insulating cement is:

$$0.5/0.80 = 0.63;\ 0.63/2 = 0.31;\ 7.26 + 0.31 = 7.57$$
$$1100 - [(7.57/8.48)(1020)] = 1100 - 911 = 189\,°\text{F}$$

From Table 10, at 663°F, $k_1 = 0.60$; at 189°F, $k_2 = 0.79$.

Using these adjusted values to recalculate q_s:

$$q_s = \frac{1020}{(4.5/0.60) + (0.5/0.79) + 0.56} = \frac{1020}{8.69}$$
$$= 117.4 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 7, at 117.4 Btu/h·ft², $R_s = 0.56$. The mean temperature of the mineral fiber block is:

$$4.5/0.6 = 7.50;\ 7.50/2 = 3.75$$
$$1100 - [(3.75/8.69)(1020)] = 1100 - 440 = 660\,°\text{F}$$

and the mean temperature of the insulating cement is:

$$0.5/0.79 = 0.63;\ 0.63/2 = 0.31;\ 7.50 + 0.31 = 7.81$$
$$1100 - [(7.81/8.69)(1020)] = 1100 - 917 = 183\,°\text{F}$$

From Table 10, at 660°F, $k_1 = 0.60$; at 183°F, $k_2 = 0.79$.

Since R_s, k_1, and k_2 do not change at these values, $q_s = 117.4$ Btu/h·ft².

Example 9. Compute heat loss per square foot of outer surface of insulation if pipe temperature is 1200°F and ambient still air temperature is 80°F. The pipe is nominal 6-in. steel pipe, insulated with a nominal 3-in. thick diatomaceous silica as the inner layer and a nominal 2-in. thick calcium silicate as the outer layer.

Solution: From Chapter 42 of the 1992 ASHRAE *Handbook—Equipment*, $r_o = 3.31$ in. A nominal 3-in. thick diatomaceous silica insulation to fit a nominal 6-in. steel pipe is 3.02 in. thick. A nominal 2-in. thick calcium silicate insulation to fit over the 3.02-in. diatomaceous silica is 2.08 in. thick. Therefore, $r_i = 6.33$ in. and $r_s = 8.41$ in.

Assume that the mean temperature of the diatomaceous silica is 600°F, the mean temperature of the calcium silicate is 250°F and the surface resistance R_s is 0.50. From Table 10, $k_1 = 0.66$; $k_2 = 0.42$. By Equation (10) from Chapter 20:

$$q_s = \frac{1200 - 80}{[8.41 \ln (6.33/3.31)/0.66] + [8.41 \ln (8.41/6.33)/0.40] + 0.50}$$
$$= \frac{1120}{(5.45/0.66) + (2.39/0.40) + 0.50} = 76.0 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 7, at 76.0 Btu/h·ft², $R_s = 0.60$. The mean temperature of the diatomaceous silica is:

$$5.45/0.66 = 8.26;\ 8.26/2 = 4.13$$
$$1200 - [(4.13/14.83)(1120)] = 1200 - 312 = 888\,°\text{F}$$

and the mean temperature of the calcium silicate is:

$$2.39/0.40 = 5.98;\ 5.98/2 = 2.99;\ 8.26 + 2.99 = 11.25$$
$$1200 - [(11.25/14.83)(1120)] = 1200 - 850 = 350\,°\text{F}$$

From Table 10, $k_1 = 0.72$; $k_2 = 0.46$. Recalculating:

$$q_s = \frac{1120}{(5.45/0.72) + (2.39/0.46) + 0.60} = 83.8 \text{ Btu/h} \cdot \text{ft}^2$$

From Figure 7 at 83.8 Btu/h·ft², $R_s = 0.59$. The mean temperature of the diatomaceous silica is:

$$5.45/0.72 = 7.57;\ 7.57/2 = 3.78$$
$$1200 - [(3.78/13.36)(1120)] = 1200 = 317 = 883\,°\text{F}$$

and the mean temperature of the calcium silicate is:

$$2.39/0.46 = 5.20;\ 5.20/2 = 2.60;\ 7.57 + 2.60 = 10.17$$
$$1200 - [(10.17/13.36)(1120)] = 1200 - 853 = 347\,°\text{F}$$

From Table 10, $k_1 = 0.72$; $k_2 = 0.46$. Recalculating:

$$q_s = \frac{1120}{(5.45/0.72) + (2.39/0.46) + 0.59} = 83.8 \text{ Btu/h} \cdot \text{ft}^2$$

Since R_s, k_1, and k_2 do not change at 83.8 Btu/h·ft², this is q_s. The heat flow per ft² of the inner surface of the insulation is:

$$q_o = q_s\,(r_s/r_o) = 83.8(8.41/3.31) = 213 \text{ Btu/h} \cdot \text{ft}^2$$

Because trial and error techniques are tedious, the computer programs previously described should be used to estimate heat flows per unit area of flat surfaces or per unit length of piping, and interface temperatures including surface temperatures.

Several methods can be used to determine the most effective thickness of insulation for piping and equipment. Table 13 shows the recommended insulation thicknesses for three different pipe and equipment insulations. Installed cost data can be developed using procedures described by the Federal Energy Administration (1976). Computer programs capable of calculating thickness information are available from several sources. Also, manufacturers of insulations offer computerized analysis programs for designers and owners to evaluate insulation requirements. For more information on determining economic insulation thickness, see Chapter 20.

Chapters 3 and 20 give guidance concerning process control, personnel protection, condensation control, and economics. For specific information on sizes of commercially available pipe insulation, see ASTM *Standard* C585 and consult with the Thermal Insulation Manufacturers Association (TIMA) and its member companies.

CALCULATING HEAT FLOW FOR BURIED PIPELINES

In calculating heat flow to or from buried pipelines, the thermal properties of the soil must be assumed. Table 7 gives the apparent thermal conductivity values of various soil types, and Figure 6 shows the typical trends of apparent soil thermal conductivity with moisture content for various soil types. Table 8 provides ranges of apparent thermal conductivity for various types of rock. Kernsten (1949) also discusses thermal properties of soils. Carslaw and Jaeger (1959) give methods for calculating the heat flow taking place between one or more buried cylinders and the surroundings.

Table 13 Recommended Thicknesses for Pipe and Equipment Insulation

		MINERAL FIBER (Fiberglass and Rock Wool)										CALCIUM		
Nominal Pipe Size, in.		**Process Temperature, °F**												
		150	**250**	**350**	**450**	**550**	**650**	**750**	**850**	**950**	**1050**	**150**	**250**	**350**
½	Thickness	1	1½	2	2½	3	3½	4	4	4½	5½	1	1½	2
	Heat loss	8	16	24	33	43	54	66	84	100	114	13	24	34
	Surface temperature	72	75	76	78	79	81	82	86	87	87	75	78	80
1	Thickness	1	1½	2	2½	3½	4	4	4½	5	5½	1	2	2½
	Heat loss	11	21	30	41	49	61	79	96	114	135	16	26	38
	Surface temperature	73	76	78	80	79	81	84	86	88	89	76	76	79
1½	Thickness	1	2	2½	3	4	4	4	5½	5½	6	1½	2½	3
	Heat loss	14	22	33	45	54	73	94	103	128	152	17	29	42
	Surface temperature	73	74	77	79	79	82	86	84	88	90	73	75	78
2	Thickness	1½	2	3	3½	4	4	4	5½	6	6	1½	2½	3
	Heat loss	13	25	34	47	61	81	105	114	137	168	19	32	47
	Surface temperature	71	75	75	77	79	83	87	85	87	91	74	76	79
3	Thickness	1½	2½	3½	4	4	4½	4½	6	6½	7	2	3	3½
	Heat loss	16	28	39	54	75	94	122	133	154	184	21	37	54
	Surface temperature	72	74	75	77	81	83	87	86	87	90	73	75	78
4	Thickness	1½	3	4	4	4	5	5½	6	7	7½	2	3	4
	Heat loss	19	29	42	63	88	102	126	152	174	206	25	43	58
	Surface temperature	72	73	74	78	82	86	85	87	88	90	70	76	77
6	Thickness	2	3	4	4	4½	5	5½	6½	7½	8	2	3½	4
	Heat loss	21	38	54	81	104	130	159	181	208	246	33	51	75
	Surface temperature	71	74	75	79	82	84	87	88	89	91	74	75	79
8	Thickness	2	3½	4	4	5	5	5½	7	8	8½	2½	3½	4
	Heat loss	26	42	65	97	116	155	189	204	234	277	35	62	90
	Surface temperature	71	73	76	80	81	86	89	88	89	92	73	76	79
10	Thickness	2	3½	4	4	5	5½	5½	7½	8½	9	2½	4	4
	Heat loss	32	50	77	115	136	170	220	226	259	307	41	66	106
	Surface temperature	72	74	77	81	82	85	90	87	89	91	73	75	80
12	Thickness	2	3½	4	4	5	5½	5½	7½	8½	9½	2½	4	4
	Heat loss	36	57	87	131	154	192	249	253	290	331	47	75	121
	Surface temperature	72	74	77	82	82	86	91	88	89	91	73	76	81
14	Thickness	2	3½	4	4	5	5½	6½	7½	9	9½	2½	4	4
	Heat loss	40	61	94	141	165	206	236	271	297	352	51	81	130
	Surface temperature	72	74	77	82	83	86	87	89	89	91	73	76	81
16	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
	Heat loss	37	68	105	157	171	228	247	284	326	372	50	90	144
	Surface temperature	71	74	78	83	82	87	86	88	89	91	72	76	82
18	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
	Heat loss	41	75	115	173	187	250	270	310	354	404	55	99	159
	Surface temperature	71	74	78	83	83	87	87	88	90	91	73	76	82
20	Thickness	2½	3½	4	4	5½	5½	7	8	9	10	3	4	4
	Heat loss	45	82	126	189	204	272	292	335	383	436	60	108	174
	Surface temperature	71	75	78	83	83	87	87	89	90	92	73	77	82
24	Thickness	2½	4	4	4	5½	6	7½	8	9	10	3	4	4
	Heat loss	53	86	147	221	237	295	320	386	439	498	71	127	203
	Surface temperature	71	74	78	83	83	86	86	89	91	93	73	77	82
30	Thickness	2½	4	4	4	5½	6½	7½	8½	10	10	3	4	4
	Heat loss	65	105	179	268	286	332	383	439	481	591	86	154	247
	Surface temperature	71	74	79	84	84	85	87	89	89	94	73	77	83
36	Thickness	2½	4	4	4	5½	7	8	9	10	10	2½	4	4
	Heat loss	77	123	211	316	335	364	422	486	556	683	119	181	291
	Surface temperature	71	74	79	84	84	84	86	88	90	94	74	77	83
Flat	Thickness	2	3½	4	4½	5½	8½	9½	10	10	10	2½	3½	4
	Heat loss	10	14	20	27	31	27	31	38	47	58	12	20	28
	Surface temperature	72	74	77	80	82	80	82	85	89	93	73	77	81

Consult manufacturer's literature for product temperature limitations. Table is based on typical operating conditions, *e.g.*, 65°F ambient temperature and 7.5 mph wind speed, and may not represent actual conditions of use. Units for thickness, heat loss, and surface temperature are in inches, Btu/h · ft (Btu/h · ft^2 for flat surfaces), and °F, respectively.

Table 13 Recommended Thicknesses for Pipe and Equipment Insulation (*Concluded*)

SILICATE							CELLULAR GLASS						
Process Temperature, °F							Process Temperature, °F						
450	550	650	750	850	950	1050	150	250	350	450	550	650	750
2½	3	3½	4	4	4	4	1½	1½	2	2½	3	3½	4
42	53	63	75	90	108	128	9	23	34	48	62	78	92
81	82	83	84	87	91	94	70	76	78	82	83	85	84
3	3½	4	4	4	4	4	1½	2	2½	3	3½	4	4
49	60	72	89	109	130	154	12	25	38	52	68	86	112
80	82	83	86	90	94	98	71	75	77	79	81	83	88
3½	4	4	4	4	5	5	1½	2½	3	4	4	4	4
54	68	86	106	128	139	164	15	28	44	56	79	105	137
80	81	85	88	92	91	94	72	75	77	78	82	87	92
3½	4	4½	5	5½	6	6	1½	2½	3	4	4	4	4½
61	75	90	106	123	142	167	17	31	47	61	84	113	140
81	82	84	85	87	88	91	72	74	77	78	82	86	89
4	4½	5	5½	6	6	6	1½	3	3½	4	4	4½	5
71	87	105	123	143	71	202	22	35	54	75	105	132	161
80	82	84	85	87	90	94	73	74	77	79	84	86	89
4	4½	5	5½	6	6½	7	2	3	4	4	4	4½	5
82	101	121	142	164	187	213	22	41	59	87	122	150	185
81	83	85	87	89	90	92	71	74	76	80	85	87	90
4	4½	5	5½	6	7	8	2	3½	4	4	4½	5½	6
105	129	153	178	205	224	245	30	48	74	111	144	171	212
83	85	87	89	91	91	91	72	74	77	82	85	86	89
4½	5	5	6	7	8	8½	2½	3½	4	4	5	5½	6½
117	144	183	200	220	243	277	30	58	90	134	161	203	238
82	85	89	89	89	90	92	71	74	78	83	84	87	89
4	5	5½	6	7½	8½	9	2½	4	4	4	5½	5½	7
149	168	200	233	243	269	306	37	63	106	159	178	238	264
85	86	88	90	89	89	91	71	74	79	84	84	87	88
4	5	5½	7	8	8½	9½	2½	4	4	4	5½	5½	7½
170	191	266	236	262	300	330	42	71	121	181	201	269	284
86	86	89	88	88	90	91	71	74	79	85	84	90	88
4	5	5½	7	8	9	9½	2½	4	4	4	5½	5½	8
183	205	242	252	262	308	352	47	79	134	199	219	293	293
86	87	89	88	88	89	91	72	74	80	85	85	91	87
4	5½	6½	7½	8	9	10	2½	4	4	4	5½	5½	8
204	211	237	265	307	338	372	53	88	149	222	242	325	322
87	85	86	87	89	90	91	72	75	80	86	86	91	88
4	5½	6½	7½	8½	9	10	2½	4	4	4	5½	5½	8
225	232	259	289	320	367	403	59	96	164	245	266	356	351
87	86	87	87	88	90	91	72	75	80	86	86	92	88
4	5½	6½	7½	8½	9½	10	2½	4	4	4½	5½	5½	8
245	252	281	312	346	381	435	64	105	179	243	289	387	379
87	86	87	88	89	90	92	72	75	81	84	86	92	88
4	5½	6½	7½	8½	9½	10	2½	4	4	5	5½	5½	8
287	293	325	360	397	437	497	76	123	209	260	336	449	436
88	87	88	88	89	90	93	72	75	81	83	87	93	89
4	5½	7	8	9	10	10	2½	4	4	5½	5½	5½	8
349	353	368	409	452	498	589	93	150	254	290	405	542	521
88	87	87	88	89	90	94	72	75	81	82	87	93	90
4	6½	7½	8	9	10	10	2½	4	4	5½	5½	5½	8
410	359	406	475	524	576	681	110	176	229	340	474	635	606
89	84	86	88	89	91	94	73	76	81	82	88	94	90
5½	6½	7½	8½	9½	10	10	2½	4	4	5½	5½	7½	8½
29	33	36	39	43	49	58	11	17	29	31	44	43	50
81	83	84	85	87	89	93	73	76	83	84	90	90	93

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Table B-2: Framed Wall Assembly U-values

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value	Metal Wall U-Value
2x4 @ 16" O.C.	11 (compressed)	0	0.098	0.202
		4	0.068	0.112
		5	0.064	0.101
		7	0.056	0.084
		8.7	0.051	0.073
	13	0	0.088	0.195
		4	0.063	0.109
		5	0.059	0.099
		7	0.052	0.082
		8.7	0.048	0.072
	15	0	0.081	0.189
		4	0.059	0.108
		5	0.055	0.097
		7	0.049	0.077
		8.7	0.045	0.071
2x4 @ 24" O.C.	11	0	0.094	0.173
		4	0.066	0.102
		5	0.062	0.093
		7	0.055	0.078
		8.7	0.050	0.069
	13	0	0.085	0.165
		4	0.061	0.099
		5	0.057	0.090
		7	0.051	0.077
		8.7	0.047	0.068
	15	0	0.077	0.158
		4	0.056	0.097
		5	0.053	0.088
		7	0.047	0.071
		8.7	0.044	0.067

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value	Metal Wall U-Value
2x6 @ 16" O.C.	19 (compressed)	0	0.065	0.120
		4	0.058	0.098
		5	0.048	0.089
		7	0.043	0.075
		8.7	0.040	0.067
	21	0	0.059	0.157
		4	0.046	0.096
		5	0.044	0.088
		7	0.041	0.075
		8.7	0.037	0.066
	22 (compressed)	0	0.062	0.158
		4	0.048	0.097
		5	0.045	0.088
		7	0.041	0.075
		8.7	0.038	0.067
2x6 @ 24" O.C.	19 (compressed)	0	0.062	0.135
		4	0.048	0.088
		5	0.045	0.081
		7	0.042	0.070
		8.7	0.039	0.062
	21	0	0.056	0.130
		4	0.044	0.086
		5	0.042	0.079
		7	0.039	0.068
		8.7	0.036	0.061
	22 (compressed)	0	0.058	0.132
		4	0.046	0.086
		5	0.043	0.079
		7	0.040	0.068
		8.7	0.037	0.061

Table B-2 (cont'd): Framed Wall Assembly U-values

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value	Metal Wall U-Value
2x8 @ 16" O.C.	19	0	0.059	0.145
		4	0.047	0.092
		5	0.044	0.084
		7	0.041	0.072
		8.7	0.038	0.064
	22	0	0.054	0.140
		4	0.043	0.090
		5	0.041	0.082
		7	0.038	0.071
		8.7	0.035	0.063
	25	0	0.050	0.136
		4	0.040	0.088
		5	0.038	0.081
		7	0.035	0.070
		8.7	0.033	0.062
	30 (compressed)	0	0.048	0.135
		4	0.039	0.088
		5	0.037	0.081
		7	0.035	0.070
		8.7	0.032	0.062
2x8 @ 24" O.C.	19	0	0.056	0.122
		4	0.045	0.082
		5	0.043	0.076
		7	0.040	0.066
		8.7	0.037	0.059
	22	0	0.051	0.117
		4	0.041	0.080
		5	0.040	0.074
		7	0.036	0.064
		8.7	0.034	0.058
	25	0	0.047	0.113
		4	0.038	0.078
		5	0.037	0.072
		7	0.034	0.063
		8.7	0.032	0.057
	30 (compressed)	0	0.046	0.112
		4	0.037	0.077
		5	0.036	0.072
		7	0.034	0.063
		8.7	0.031	0.057

Framing Type and Spacing	Framing Cavity R-Value	Insulated Sheathing R-Value	Wood Wall U-Value	Metal Wall U-Value
2x10 @ 16" O.C.	30	0	0.041	0.120
		4	0.035	0.081
		5	0.033	0.075
		7	0.031	0.065
		8.7	0.029	0.059
	38 (compressed)	0	0.040	0.119
		4	0.033	0.080
		5	0.032	0.074
		7	0.030	0.065
		8.7	0.028	0.058
2x10 @ 24" O.C.	30 (compressed)	0	0.039	0.099
		4	0.033	0.071
		5	0.032	0.066
		7	0.030	0.058
		8.7	0.028	0.053
	38	0	0.038	0.097
		4	0.032	0.070
		5	0.031	0.066
		7	0.029	0.058
		8.7	0.027	0.053

Table B-2a: Solar Heat Gain Coefficients Used for Exterior Shading[1]

Exterior Shading Device	SHGC
Standard Bug Screens	0.76
Exterior Sunscreens with weave 53*16/inch	0.30
Louvered Sunscreens with louvers as wide as openings	0.27
Low Sun Angle (LSA) Louvered Sunscreens	0.13
Roll-down Awning	0.13
Roll Down Blinds or Slats	0.13
None (for skylights only)	1.00
1) Exterior operable awnings (canvas, plastic or metal), except those that roll vertically down and cover the entire window, should be treated as overhangs for purposes of compliance with the Standards.	

Table B-3: Metal Framing Factor

METAL FRAMING FACTORS			
Stud Spacing	Stud Depth	Insulation R-Value	Framing Factor
16" o.c.	4"	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6"	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24" o.c.	4"	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6"	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308
R-value calculation for Exterior Wall Assemblies with Metal Studs, July, 19, 1990, Staff Draft Docket 90-CON-1.			
*Correction to metal framing factors applies to the entire assembly including: interior air films, interior surfaces, cavity/insulation, exterior surfaces, and exterior air films.			

Table B-4: Properties of Hollow Unit Masonry Walls

Type			Core Treatment		
			Solid Grout	Partly Grouted with Ungrouted Cells	
				Empty	Insulated
12"	LW CMU	U	0.51	0.43	0.30
		Rw	2.0	2.3	3.3
		HC	23	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		Rw	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rw	1.8	2.0	2.8
		HC	24.8	16.5	16.5
10"	LW CMU	U	0.55	0.46	0.34
		Rw	1.8	2.2	2.9
		HC	18.9	12.6	12.6
	MW CMU	U	0.59	0.49	0.37
		Rw	1.7	2.1	2.7
		HC	19.7	13.4	13.4
	NW CMU	U	0.62	0.52	0.41
		Rw	1.6	1.9	2.4
		HC	20.5	14.2	14.2
8"	LW CMU	U	0.62	0.50	0.37
		Rw	1.6	2.0	2.7
		HC	15.1	9.9	9.9
	MW CMU	U	0.65	0.53	0.41
		Rw	1.5	1.9	2.4
		HC	15.7	10.5	10.5
	NW CMU	U	0.69	0.56	0.44
		Rw	1.4	1.8	2.3
		HC	16.3	11.1	11.1
	Clay Unit	U	0.57	0.47	0.39
		Rw	1.8	2.1	2.6
		HC	15.1	11.4	11.4
6"	LW CMU	U	0.68	0.54	0.44
		Rw	1.5	1.9	2.3
		HC	10.9	7.9	7.9
	MW CMU	U	0.72	0.58	0.48
		Rw	1.4	1.7	2.1
		HC	11.4	8.4	8.4
	NW CMU	U	0.76	0.61	0.52
		Rw	1.3	1.6	1.9
		HC	11.9	8.9	8.9
	Clay Unit	U	0.65	0.52	0.45
		Rw	1.5	1.9	2.2
		HC	11.1	8.6	8.6

Notes:
LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90, Calculated at 105 PCF density
MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90, Calculated at 115 PCF density
NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90, Calculated at 125 PCF density
Clay Unit is a Hollow Clay Unit per ASTM C 652, Calculated at 130 PCF density
Values include air films on inner and outer surfaces.
Calculations based on Energy Calculations and Data, CMACN, 1986
Grouted Cells at 32" X 48" in Partly Grouted Walls
Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada

Table B-5: Properties of Solid Unit Masonry and Solid Concrete Walls

Type		Layer Thickness, inches									
		3	4	5	6	7	8	9	10	11	12
LW CMU	U	na	0.71	0.64	na	na	na	na	na	na	na
	Rw	na	1.4	1.6	na	na	na	na	na	na	na
	HC	na	7.00	8.75	na	na	na	na	na	na	na
MW CMU	U	na	0.76	0.70	na	na	na	na	na	na	na
	Rw	na	1.3	1.4	na	na	na	na	na	na	na
	HC	na	7.67	9.58	na	na	na	na	na	na	na
NW CMU	U	0.89	0.82	0.76	na	na	na	na	na	na	na
	Rw	1.1	1.2	1.3	na	na	na	na	na	na	na
	HC	6.25	8.33	10.42	na	na	na	na	na	na	na
Clay Brick	U	0.80	0.72	0.66	na	na	na	na	na	na	na
	Rw	1.3	1.4	1.5	na	na	na	na	na	na	na
	HC	6.30	8.40	10.43	na	na	na	na	na	na	na
Concrete	U	0.96	0.91	0.86	0.82	0.78	0.74	0.71	0.68	0.65	0.63
	Rw	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6
	HC	7.20	9.60	12.00	14.40	16.80	19.20	21.60	24.00	26.40	28.80

Notes:
LW CMU is a Light Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 105 PCF density
MW CMU is a Medium Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 115 PCF density
NW CMU is a Normal Weight Concrete Masonry Unit per ASTM C 90 or 55, Calculated at 125 PCF density
Clay Brick is a Clay Unit per ASTM C 62, Calculated at 130 PCF density
Concrete is stuctural poured or precast concrete, Calculated at 144 PCF density
Calculations based on Energy Calculations and Data, CMACN, 1986
Values include air films on inner and outer surfaces.
Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada

Table B-6: Effective R-values for Interior Insulation Layers on Structural Mass Walls

Type Actual Thick	Frame	Furring space R-value without framing effects																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Any	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5
0.5"	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
0.75"	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1.0"	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	na	na	na	na	na	na	na	na	na	na	na	na	na
1.5"	Wood	1.3	1.5	2.4	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.5	6.8	7.1	na	na	na	na	na	na	na	na	na
	Metal	1.1	1.2	1.6	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7	na	na	na	na	na	na	na	na	na
2"	Wood	1.4	1.5	2.5	3.3	4.0	4.7	5.3	5.9	6.4	6.9	7.3	7.7	8.1	8.4	8.7	9.0	9.3	na	na	na	na	na
	Metal	1.1	1.2	1.7	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.3	3.4	3.4	na	na	na	na	na
2.5"	Wood	1.4	1.5	2.5	3.4	4.2	4.9	5.6	6.3	6.8	7.4	7.9	8.4	8.8	9.2	9.6	10.0	10.3	10.6	10.9	11.2	11.5	na
	Metal	1.2	1.3	1.8	2.3	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	na
3"	Wood	1.4	1.5	2.5	3.5	4.3	5.1	5.8	6.5	7.2	7.8	8.3	8.9	9.4	9.9	10.3	10.7	11.1	11.5	11.9	12.2	12.5	12.9
	Metal	1.2	1.3	1.9	2.4	2.8	3.1	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8
3.5"	Wood	1.4	1.5	2.6	3.5	4.4	5.2	6.0	6.7	7.4	8.1	8.7	9.3	9.8	10.4	10.9	11.3	11.8	12.2	12.6	13.0	13.4	13.8
	Metal	1.2	1.3	2.0	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.2	5.3
4"	Wood	1.4	1.6	2.6	3.6	4.5	5.3	6.1	6.9	7.6	8.3	9.0	9.6	10.2	10.8	11.3	11.9	12.4	12.8	13.3	13.7	14.2	14.6
	Metal	1.2	1.3	2.0	2.6	3.0	3.4	3.7	4.0	4.2	4.5	4.6	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8
4.5"	Wood	1.4	1.6	2.6	3.6	4.5	5.4	6.2	7.1	7.8	8.5	9.2	9.9	10.5	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.2
	Metal	1.2	1.3	2.1	2.6	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3
5"	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.3	7.2	8	8.7	9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.3	15.8
	Metal	1.2	1.4	2.1	2.7	3.2	3.7	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.7	6.8
5.5"	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.4	7.3	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.7	15.3	15.8	16.3
	Metal	1.3	1.4	2.1	2.8	3.3	3.8	4.2	4.6	4.9	5.2	5.4	5.7	5.9	6.1	6.3	6.4	6.6	6.7	6.8	7.0	7.1	7.2

All furring thickness values given are actual dimensions

All values include .5" gypbd. on the inner surface, interior surface resistances not included

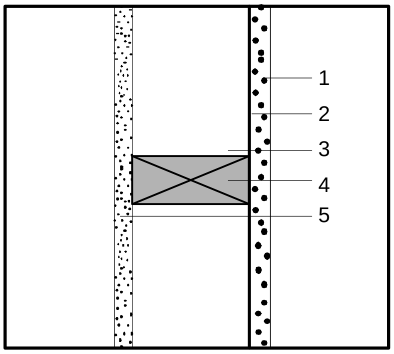
24" OC Furring 24 Gage, Z-type Metal Furring Douglas-Fir Larch Wood Furring, density = 34.9 lb/cu.ft.

Insulation assumed to fill the furring space

[Source: Berkeley Solar Group; Concrete Masonry Association of California and Nevada]

Table B-7: Framed Wall/Floor/Ceiling Assembly U-Values

Reference Name: **W.0.2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 4
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)
- Wall: ✓ 15% (16"o.c.); 12% (24"o.c.); 9% (48"o.c.)
- Floor/Ceiling: 10% (16"o.c.); 7% (24"o.c.); 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.600
3.	3.5" & greater air space; heat sideways	0.850	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	2.385	5.000
		R_c	R_f

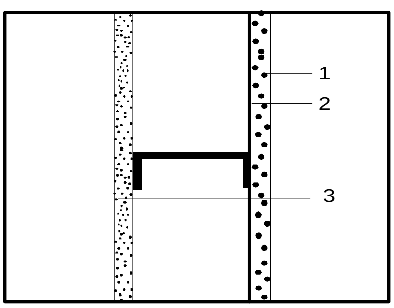
Framing Adjustment Calculation:

[(1/2.385) × (1-15/100)] + [(1/5.00) × (15/100)] = **0.385** **Total U-Value**

(1÷R_c) (1-(Fr.% ÷100)) (1÷R_f) (Fr.% ÷100)

1/0.385 (1÷Total U-Value) = 2.591 **Total R-Value**

Reference Name: **W.0.2x4.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.
Framing Size: Actual Depth 3.625; Actual Width 1.625
Cavity Insulation: R-value 0.850; Knock-out (%) 15.00; Web Thickness 0.060
Insulation Tape R-value: Interior Flange 0.0; Exterior Flange 0.0

List of Construction Components

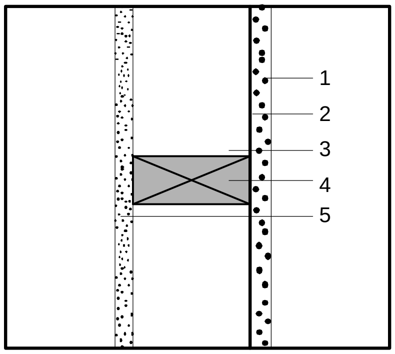
	Component	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.50 in gypsum or plaster board	0.450
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.449** **Total U-Value**

1/0.449 (1÷Total U-Value) = 2.23 **Total R-Value**

Reference Name: W.0.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
	✓	12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.600
3.	3.5" & greater air space; heat sideways	0.850	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	2.385	5.000
		R_c	R_f

Framing Adjustment Calculation:

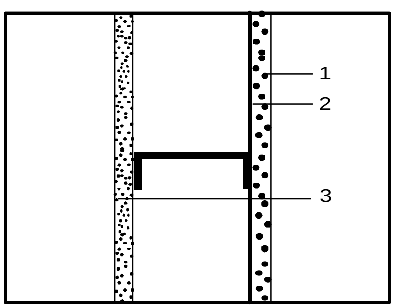
[(1/2.385) × (1-12/100)] + [(1/5.000) × (12/100)] = **0.393**

($1 \div R_c$) ($1-(\text{Fr.}\% \div 100)$) ($1 \div R_f$) ($\text{Fr.}\% \div 100$)

Total U-Value

1/0.393 (1÷Total U-Value) = 2.546 **Total R-Value**

Reference Name: W.0.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	0.850
	Knock-out (%)	15.00
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	0.0
	Exterior Flange	0.0

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.50 in gypsum or plaster board	0.450
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.680

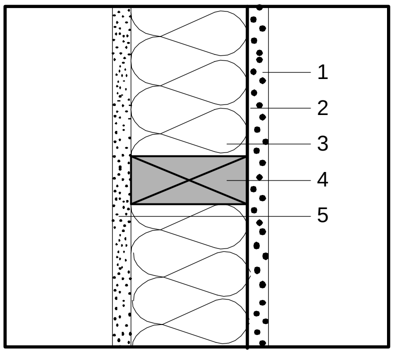
Calculation:

From EZFRAME = **0.443**

Total U-Value

1/0.443 (1÷Total U-Value) = 2.260 **Total R-Value**

Reference Name: W.7.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 4
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)
Wall: ✓ 15% (16"o.c.); 12% (24"o.c.); 9% (48"o.c.)
Floor/Ceiling: 10% (16"o.c.); 7% (24"o.c.); 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.600
3.	R-7 fiberglass insulation	7.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	8.535	5.000
		R_c	R_f

Framing Adjustment Calculation:

[(1/8.535) × (1-15/100)] + [(1/5.00) × (15/100)] = **0.130**

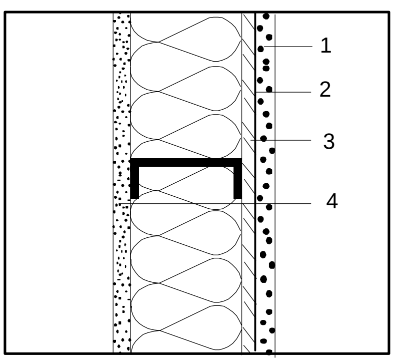
($1 \div R_c$; 1-(Fr.% ÷100); $1 \div R_f$; Fr.% ÷100)

Total U-Value

1/0.130 (1÷Total U-Value) = 7.69

Total R-Value

Reference Name: W.7.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.
Framing Size: Actual Depth 3.625; Actual Width 1.625
Cavity Insulation: R-value 7.00; Knock-out (%) 15.00; Web Thickness 0.0600
Insulation Tape R-value: Interior Flange 0.0; Exterior Flange 0.0

List of Construction Components

	Component	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.50 in polyisocyanurate	3.500
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

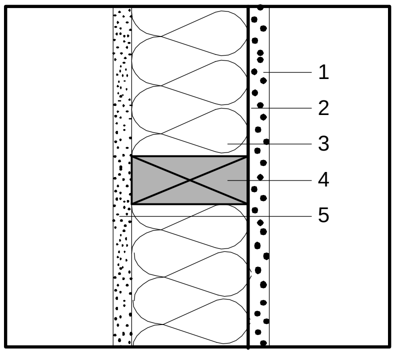
From EZFRAME = **0.125**

Total U-Value

1/0.125 (1÷Total U-Value) = 7.990

Total R-Value

Reference Name: W.7.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)

- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

- Wall:
  - 15% (16"o.c.)
  - ✓ 12% (24"o.c.)
  - 9% (48"o.c.)
- Floor/Ceiling:
  - 10% (16"o.c.)
  - 7% (24"o.c.)
  - 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.600
3.	R-7 Fiberglass Insulation	7.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	8.535 (R_c)	5.000 (R_f)

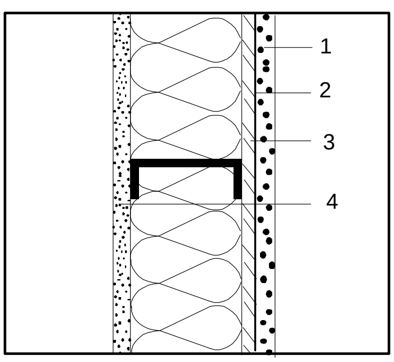
Framing Adjustment Calculation:

$$[(1/8.535)_{1 \div R_c} \times (1\text{-}15/100)_{1-(\text{Fr.\%} \div 100)}] + [(1/5.00)_{1 \div R_f} \times (15/100)_{\text{Fr.\%} \div 100}] = 0.127$$

Total U-Value = **0.127**

$1/0.127$ (1÷Total U-Value) = 7.874 **Total R-Value**

Reference Name: W.7.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)

- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size:

- Actual Depth: 3.625
- Actual Width: 1.625

Cavity Insulation:

- R-value: 7.00
- Knock-out (%): 15.00
- Web Thickness: 0.0600

Insulation Tape R-value:

- Interior Flange: 0.0
- Exterior Flange: 0.0

List of Construction Components

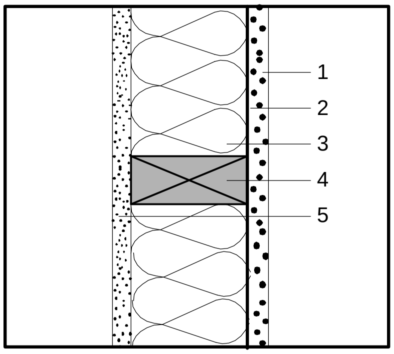
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.50 in polyisocyanurate	3.500
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.117** **Total U-Value**

$1/0.117$ (1÷Total U-Value) = 8.530 **Total R-Value**

Reference Name: W.11.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 4
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)
- Wall: ✓ 15% (16"o.c.)
- 12% (24"o.c.)
- 9% (48"o.c.)
- Floor/Ceiling 10% (16"o.c.)
- 7% (24"o.c.)
- 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		**R-Value Cavity (R_c)**	**R-Value Frame (R_f)**
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	R-11 fiberglass insulation	11.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	12.535	5.00
		R_c	R_f

Framing Adjustment Calculation:

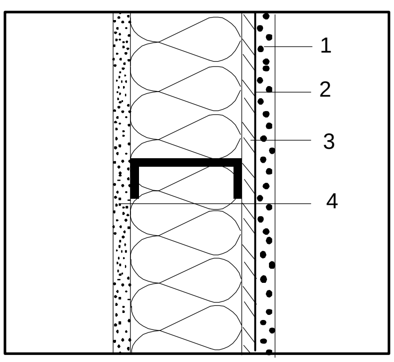
$$[(1/12.535)_{1\div R_c} \times (1-15/100)_{1-(Fr.\% \div 100)}] + [(1/5.00)_{1\div R_f} \times (15/100)_{Fr.\% \div 100}] = 0.098$$

0.098 Total U-Value

$$\frac{1/0.098}{1\div \text{Total U-Value}} = 10.204$$

10.204 Total R-Value

Reference Name: W.11.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.
Framing Size:
- Actual Depth 3.625
- Actual Width 1.625

Cavity Insulation:
- R-value 11.00
- Knock-out (%) 15.00
- Web Thickness 0.060

Insulation Tape R-value:
- Interior Flange 0.0
- Exterior Flange 0.0

List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.250
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

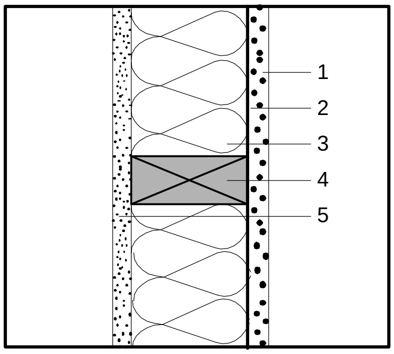
Calculation:

From EZFRAME = **0.096 Total U-Value**

$$\frac{1/0.096}{1\div \text{Total U-Value}} = 10.360$$

10.360 Total R-Value

Reference Name: W.11.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
	✓	12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. 0.875 in stucco	0.175	0.175
2. Building paper (felt)	0.060	0.600
3. R-11 fiberglass insulation	11.00	-----
4. 2x4 in fir framing	-----	3.465
5. 0.50 in gypsum or plaster board	0.450	0.450
6.		
7.		
Inside Surface Air Film	0.680	0.680
Total Unadjusted R-Values:	12.535	5.00
	R_c	R_f

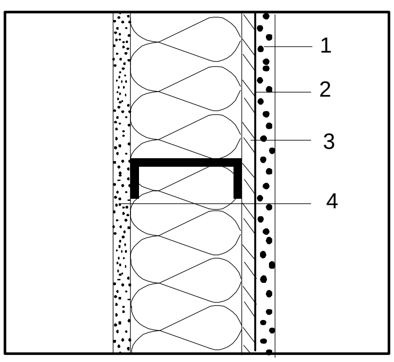
Framing Adjustment Calculation:

$$\left[\left(\frac{1}{12.535}\right)_{1\div R_c} \times \left(1-\frac{12}{100}\right)_{1-(\text{Fr.\%}\div 100)}\right] + \left[\left(\frac{1}{5.00}\right)_{1\div R_f} \times \left(\frac{12}{100}\right)_{\text{Fr.\%}\div 100}\right] = 0.094$$

0.094
Total U-Value

1/0.094 (1÷Total U-Value) = 10.638 **Total R-Value**

Reference Name: W.11.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.000
	Knock-out (%)	15.000
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	0.0
	Exterior Flange	0.0

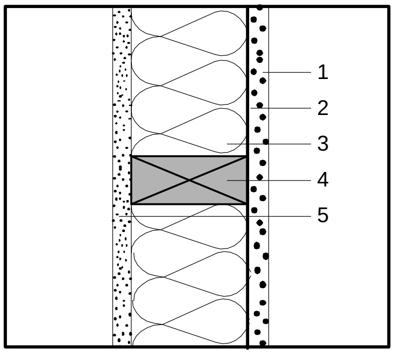
List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 0.875 in stucco	0.175
2. Building paper (felt)	0.060
3. 0.75 in polyisocyanurate	5.250
4. 0.50 in gypsum or plaster board	0.450
5.	
6.	
7.	
Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.090**
Total U-Value

1/0.090 (1÷Total U-Value) = 11.140 **Total R-Value**

Reference Name: W.13.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:	✓	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: NA (Packages only)

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.600
3.	R-13 fiberglass insulation	13.00	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	14.535	5.00
		R_c	R_f

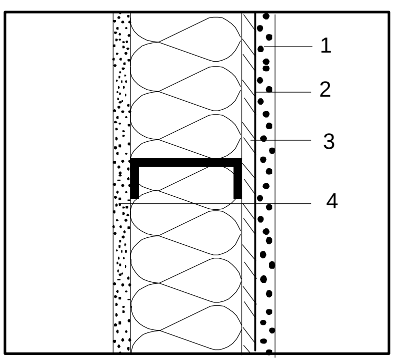
Framing Adjustment Calculation:

[(1/14.535) × (1-15/100)] + [(1/5.00) × (15/100)] = **0.088** **Total U-Value**

(1÷R^c; 1-(Fr.% ÷100); 1÷R^f; Fr.% ÷100)

1/0.088 (1÷Total U-Value) = 11.364 **Total R-Value**

Reference Name: W.13.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 13.000; Knock-out (%) 15.00; Web Thickness 0.060

Insulation Tape R-value: Interior Flange 0.0; Exterior Flange 0.0

List of Construction Components

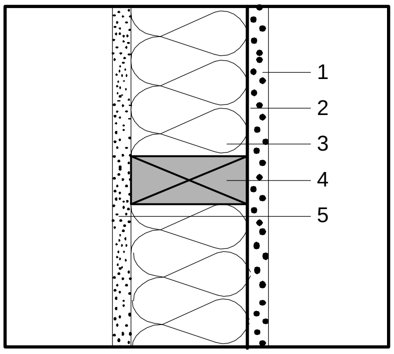
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	1.00 in Polyisocyanurate	7.000
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.081** **Total U-Value**

1/0.081 (1÷Total U-Value) = 12.330 **Total R-Value**

Reference Name: W.13.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)
- Wall:
  - 15% (16"o.c.)
  - ✓ 12% (24"o.c.)
  - 9% (48"o.c.)
- Floor/Ceiling
  - 10% (16"o.c.)
  - 7% (24"o.c.)
  - 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.600
3.	R-13 fiberglass insulation	13.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	14.535	5.00
		R_c	R_f

Framing Adjustment Calculation:

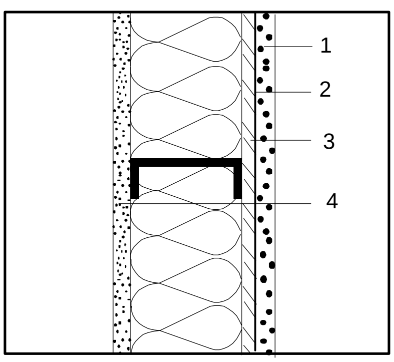
$$\left[\left(\frac{1/14.535}{1 \div R^c}\right) \times \left(\frac{1-12/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/5.00}{1 \div R^f}\right) \times \left(\frac{12/100}{\text{Fr.}\% \div 100}\right)\right] = 0.085$$

0.085
Total U-Value

$$\frac{1/0.085}{1 \div \text{Total U-Value}} = 10.620$$

Total R-Value

Reference Name: W.13.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size:
- Actual Depth: 3.625
- Actual Width: 1.625

Cavity Insulation:
- R-value: 13.00
- Knock-out (%): 15.00
- Web Thickness: 0.060

Insulation Tape R-value:
- Interior Flange: 0.0
- Exterior Flange: 0.0

List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.250
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

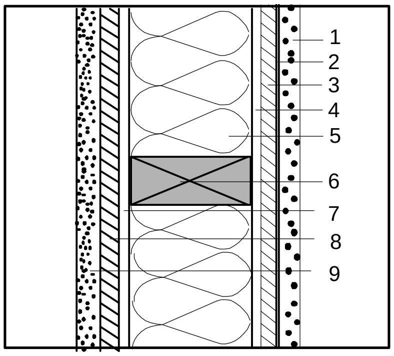
From EZFRAME = **0.087**

Total U-Value

$$\frac{1/0.087}{1 \div \text{Total U-Value}} = 11.460$$

Total R-Value

Reference Name: WP.14.2x4.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 48 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
	✓	9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in Furring Channel	0.800	0.800
5.	3 5/8 in EPS foam insulation @ R-3.85/in	13.956	-----
6.	2X4 in fir framing	-----	3.465
7.	0.875 in Furring Channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	18.031	7.540
		R_c	R_f

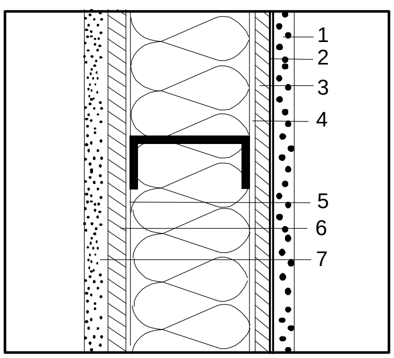
Framing Adjustment Calculation:

[(1/18.031) × (1-9/100)] + [(1/7.540) × (9/100)] = **0.062** **Total U-Value**

(1÷R; 1-(Fr.% ÷100); 1÷R; Fr.% ÷100)

1/0.062 (1÷Total U-Value) = 16.129 **Total R-Value**

Reference Name: WP.14.2x4.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 48 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 14.00; Knock-out (%) 15.00; Web Thickness 0.060

Insulation Tape R-value: Interior Flange 0.0; Exterior Flange 0.0

List of Construction Components

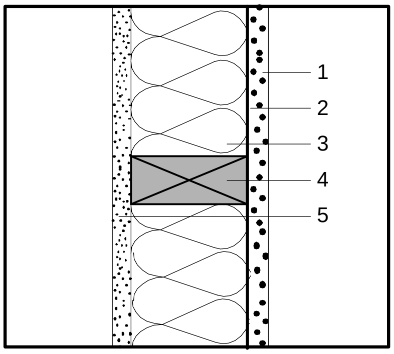
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	1.00 in polyisocyanurate	7.000
4.	0.875 in Furring Channel	0.800
5.	0.875 in Furring Channel	0.800
6.	0.375 in plywood	0.470
7.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.062** **Total U-Value**

1/0.062 (1÷Total U-Value) = 16.26 **Total R-Value**

Reference Name: W.15.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one): Floor ___ ; Wall ✓ ; Ceiling/Roof ___

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:	✓	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

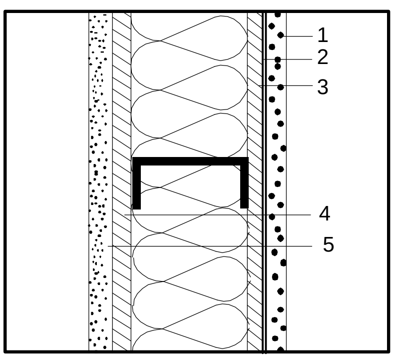
	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	R-15 fiberglass insulation	15.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	16.353	5.000
		R_c	R_f

Framing Adjustment Calculation:

[(1/16.535) (1÷Rc) × (1-15/100)] (1-(Fr.% ÷100)) + [(1/5.00) (1÷R_f) × (15/100)] (Fr.% ÷100) = **0.081** **Total U-Value**

1/0.081 (1÷Total U-Value) = 12.346 **Total R-Value**

Reference Name: W.15.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one): Floor ___ ; Wall ✓ ; Ceiling/Roof ___

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 15.00; Knock-out (%) 15.00; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___ ; Exterior Flange ___

List of Construction Components

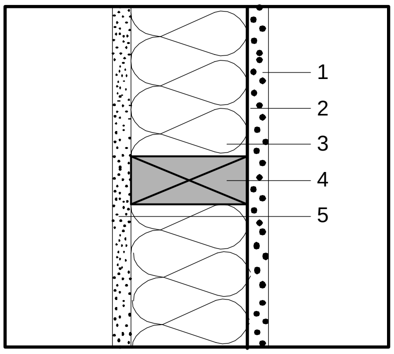
	Component	R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.50 in Polyisocyanurate	3.500
4.	0.50 in Polyisocyanurate	3.500
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.080** **Total U-Value**

1/0.080 (1÷Total U-Value) = 12.510 **Total R-Value**

Reference Name: W.15.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
	✓	Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 4	
Framing Spacing:	24	"o.c.
Framing Percentage: (check one)	Wall:	15% (16"o.c.)
	✓	12% (24"o.c.)
		9% (48"o.c.)
	Floor/Ceiling	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components		**R-Value** Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	R-15 fiberglass insulation	15.000	-----
4.	2x4 in fir framing	-----	3.465
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	16.535	5.00
		R_c	R_f

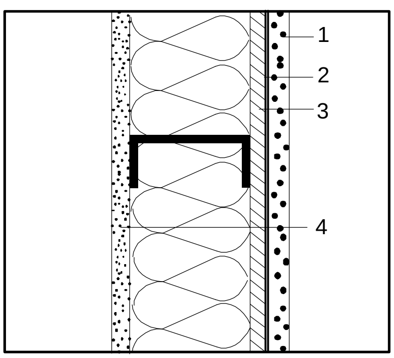
Framing Adjustment Calculation:

[(1/16.535) × (1-12/100)] + [(1/5.00) × (12/100)] = **0.077** **Total U-Value**

1÷Rc; 1-(Fr.% ÷100); 1÷R_f; Fr.% ÷100

1/0.077 (1÷Total U-Value) = 12.987 **Total R-Value**

Reference Name: W.15.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
	✓	Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	24	"o.c.
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	15.00
	Knock-out (%)	15.00
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

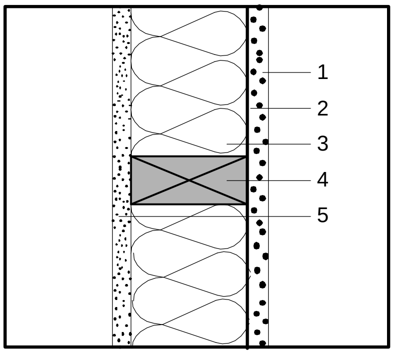
List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	1 in Polyisocyanurate	7.000
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.074** **Total U-Value**

1/0.074 (1÷Total U-Value) = 13.470 **Total R-Value**

Reference Name: W.19.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 6
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)
Wall: ✓ 15% (16"o.c.) / 12% (24"o.c.) / 9% (48"o.c.)
Floor/Ceiling: 10% (16"o.c.) / 7% (24"o.c.) / 4% (48"o.c.)

Wall Weight / sf: NA (Packages only)

List of Construction Components — **R-Value**

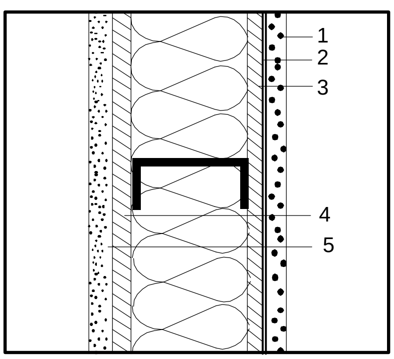
		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	R-19 fiberglass inuslation	17.800	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	19.335	6.980
		R_c	R_f

Framing Adjustment Calculation:

[(1/19.335) (1÷Rc) × (1-15/100)] (1-(Fr.% ÷100)) + [(1/6.98) (1÷Rf) × (15/100)] (Fr.% ÷100) = **0.065** **Total U-Value**

1/0.065 (1÷Total U-Value) = 15.385 **Total R-Value**

Reference Name: W.19.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.
Framing Size: Actual Depth 6.000; Actual Width 1.625
Cavity Insulation: R-value 19.00; Knock-out (%) 15.00; Web Thickness 0.060
Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components — **R-Value**

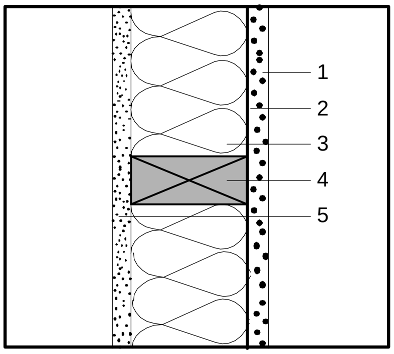
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.75 in polyiscyanurate	5.250
4.	0.50 in polyiscyanurate	3.500
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.064** **Total U-Value**

1/0.064 (1÷Total U-Value) = 15.530 **Total R-Value**

Reference Name: W.19.2x6.24



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 6
Framing Spacing: 24 "o.c.
Framing Percentage: (check one)
- Wall: 15% (16"o.c.)
- ✓ 12% (24"o.c.)
- 9% (48"o.c.)
- Floor/Ceiling: 10% (16"o.c.)
- 7% (24"o.c.)
- 4% (48"o.c.)

Wall Weight / sf: NA
(Packages only)

List of Construction Components		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	R-19 fiberglass insulation	17.800	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	19.335	6.980
		R_c	R_f

Framing Adjustment Calculation:

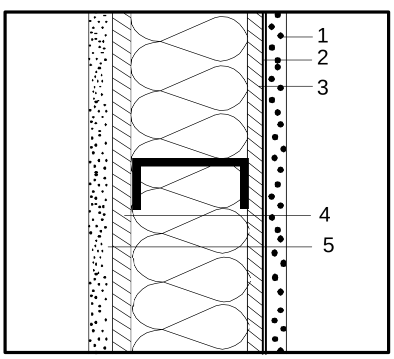
[(1/19.335) × (1-12/100)] + [(1/6.980) × (12/100)] = **0.063**

1÷Rc; 1-(Fr.% ÷100); 1÷Rf; Fr.% ÷100

Total U-Value

1/0.063 (1÷Total U-Value) = 15.873 **Total R-Value**

Reference Name: W.19.2x6.24



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 24 "o.c.
Framing Size: Actual Depth 6.000; Actual Width 1.625
Cavity Insulation: R-value 19.00; Knock-out (%) 15.00; Web Thickness 0.060
Insulation Tape R-value: Interior Flange ; Exterior Flange

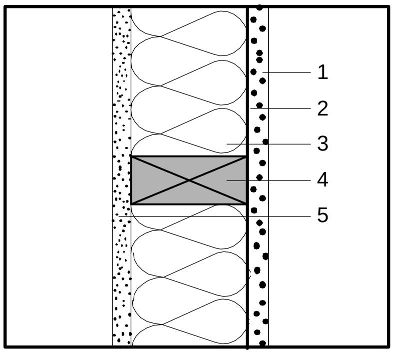
List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	0.75 in polyisocyanurate	5.250
4.	0.50 in polyisocyanurate	3.500
5.	0.50 in gypsum board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.060** **Total U-Value**

1/0.060 (1÷Total U-Value) = 16.750 **Total R-Value**

Reference Name: W.21.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)

		Floor
	✓	Wall
		Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
	✓	12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: NA (Packages only)

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	R-21 fiberglass insulation	21.000	-----
4.	2x6 in fir framing	-----	5.445
5.	0.50 in gypsum or plaster board	0.450	0.450
6.			
7.			
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	22.535	6.980
		R_c	R_f

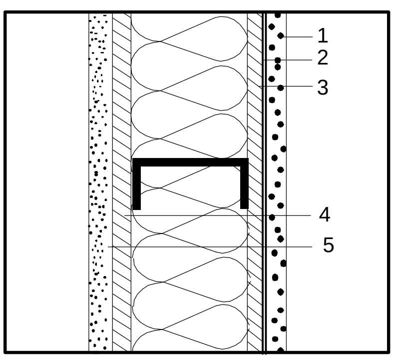
Framing Adjustment Calculation:

[(1/22.535) × (1-15/100)] + [(1/6.980) × (15/100)] = **0.059** **Total U-Value**

(1÷R; 1-(Fr.% ÷100); 1÷Rf; Fr.% ÷100)

1/0.059 (1÷Total U-Value) = 16.949 **Total R-Value**

Reference Name: W.21.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)

		Floor
	✓	Wall
		Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 21.00; Knock-out (%) 15.00; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components

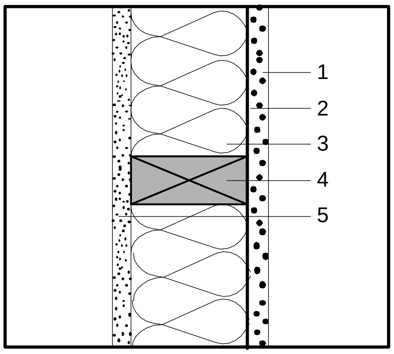
		R-Value
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	1.0 in polyisocyanurate	7.000
4.	0.5 in polyisocyanurate	3.500
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.057** **Total U-Value**

1/0.057 (1÷Total U-Value) = 17.440 **Total R-Value**

Reference Name: **W.21.2x6.24**



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 6
Framing Spacing: 24 "o.c.
Framing Percentage: (check one)
- Wall: 15% (16"o.c.)
- ✓ 12% (24"o.c.)
- 9% (48"o.c.)
- Floor/Ceiling: 10% (16"o.c.)
- 7% (24"o.c.)
- 4% (48"o.c.)

Wall Weight / sf: NA
(Packages only)

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. 0.875 in stucco	0.175	0.175
2. Building paper (felt)	0.060	0.060
3. R-21 fiberglass insulation	21.000	-----
4. 2x6 in fir framing	-----	3.465
5. 0.50 in gypsum or plaster board	0.450	0.450
6.		
7.		
Inside Surface Air Film	0.680	0.680
Total Unadjusted R-Values:	22.535	6.980
	R_c	R_f

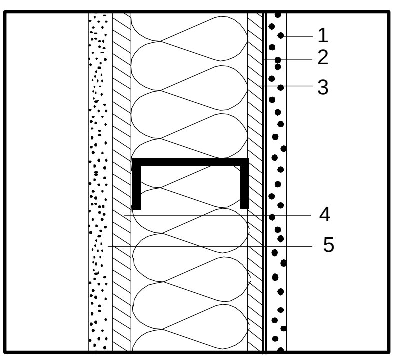
Framing Adjustment Calculation:

[(1/22.535) × (1-12/100)] + [(1/6.98) × (12/100)] = **0.056** **Total U-Value**

(1÷Rc) (1-(Fr.% ÷100)) (1÷R_f) (Fr.% ÷100)

1/0.056 (1÷Total U-Value) = 17.857 **Total R-Value**

Reference Name: **W.21.2x6.24**



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- ✓ Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 24 "o.c.
Framing Size: Actual Depth 6.000; Actual Width 1.625
Cavity Insulation: R-value 21.00; Knock-out (%) 15.00; Web Thickness 0.060
Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

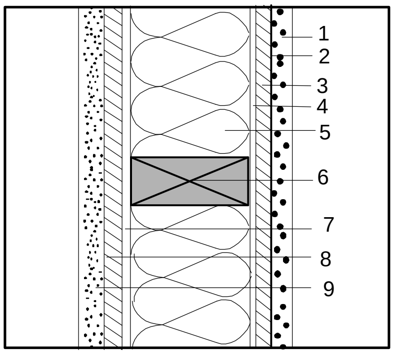
List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 0.875 in stucco	0.175
2. Building paper (felt)	0.060
3. 1.0 in polyisocyanurate	7.000
4. 0.5 in polyisocyanurate	3.500
5. 0.50 in gypsum or plaster board	0.450
6.	
7.	
Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.053** **Total U-Value**

1/0.053 (1÷Total U-Value) = 18.720 **Total R-Value**

Reference Name: WP.22.2x6.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 48 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
	✓	9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: NA
(Packages only)

List of Construction Components		**R-Value** Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.175	0.175
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in Furring Channel	0.800	0.800
5.	R-21.656 EPS foam insulation	21.656	-----
6.	2X6 in fir framing	-----	5.445
7.	0.875 in Furring Channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.680	0.680
	Total Unadjusted R-Values:	25.731	9.520
		R_c	R_f

Framing Adjustment Calculation:

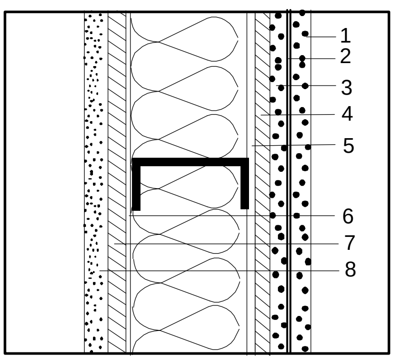
$$[(1/25.731) \times (1-9/100)] + [(1/9.52) \times (9/100)] = 0.044$$

(1÷R c) × (1-(Fr.% ÷100)) + (1÷R_f) × (Fr.% ÷100)

0.044
Total U-Value

1/0.044 (1÷Total U-Value) = 22.727 **Total R-Value**

Reference Name: WP.22.2x6.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
✓	Wall
	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 48 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 21.700; Knock-out (%) 15.00; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

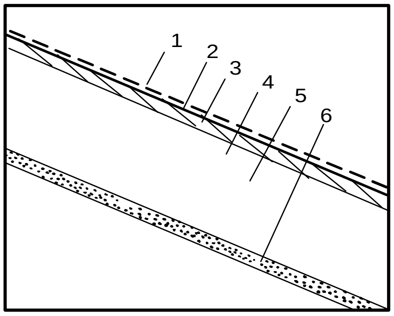
List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	0.875 in stucco	0.175
2.	Building paper (felt)	0.060
3.	1.50 in polyisocyanurate	10.500
4.	0.50 in plywood	0.630
5.	0.875 in Furring channel	0.800
6.	0.875 in Furring channel	0.800
7.	0.50 in plywood	0.630
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.680

Calculation:

From EZFRAME = **0.044**
Total U-Value

1/0.044 (1÷Total U-Value) = 22.83 **Total R-Value**

Reference Name: R.0.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.5 in & greater air space; heat flow up	**0.800**	-----
5.	2x6 in fir framing	-----	5.445
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	3.150	7.795
		R_c	R_f

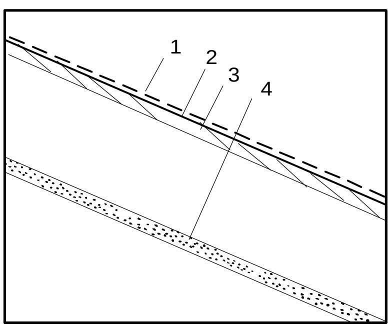
Framing Adjustment Calculation:

[(1/3.150) × (1-10/100)] + [(1/7.795) × (10/100)] = **0.298 Total U-Value**

($1 \div R_c$; 1-(Fr.% ÷100); $1 \div R_f$; Fr.% ÷100)

1/0.298 (1÷Total U-Value) = 3.356 **Total R-Value**

Reference Name: R.0.2X6.16



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 0.800; Knock-out (%) 15.00; Web Thickness 0.06

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components

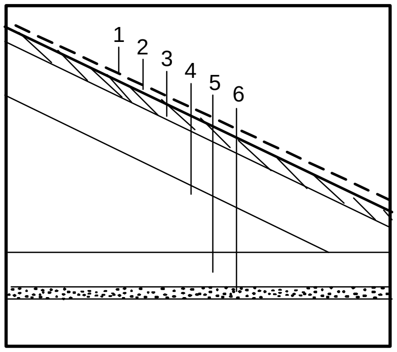
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	0.50 in gypsum or plaster board	0.450
5.		
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.323 Total U-Value**

1/0.323 (1÷Total U-Value) = 3.090 **Total R-Value**

Reference Name: **R.0.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)	___	Floor	
	___	Wall	
	✓	Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 4		
Framing Spacing:	24 "o.c.		
Framing Percentage: (check one)	Wall:	___	15% (16"o.c.)
		___	12% (24"o.c.)
		___	9% (48"o.c.)
	Floor/Ceiling	___	10% (16"o.c.)
		✓	7% (24"o.c.)
		___	4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.5" & greater air space; heat sidways	0.800	0.800
5.	2x4 in fir framing	-----	3.465
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	3.150	6.615
		R_c	R_f

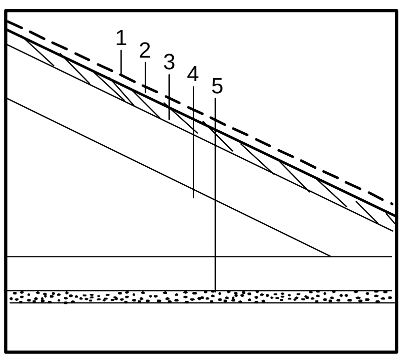
Framing Adjustment Calculation:

$$\left[\left(\underset{1\div R_c}{1/3.150}\right) \times \left(\underset{1-(\text{Fr.\%}\div 100)}{1-7/100}\right)\right] + \left[\left(\underset{1\div R_f}{1/6.615}\right) \times \left(\underset{\text{Fr.\%}\div 100}{7/100}\right)\right] = \boxed{0.306}$$

Total U-Value

$$\underset{1\div \text{Total U-Value}}{1/0.306} = \underset{\text{Total R-Value}}{3.268}$$

Reference Name: **R.0.2X4.24**



Sketch of Construction Assembly

Assembly Type: (check one)	___	Floor
	___	Wall
	✓	Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	24 "o.c.	
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	0.800
	Knock-out (%)	15.00
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.5" & greater air space; heat sidways	0.800
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.610

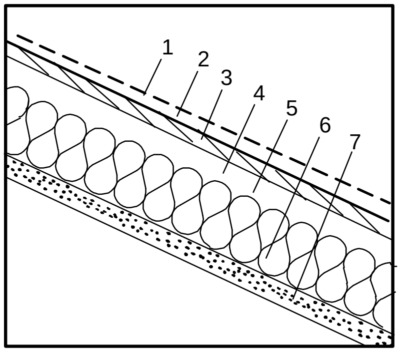
Calculation:

From EZFRAME = **0.316**

Total U-Value

$$\underset{1\div \text{Total U-Value}}{1/0.316} = \underset{\text{Total R-Value}}{3.160}$$

Reference Name: R.11.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:	___	15% (16"o.c.)
	___	12% (24"o.c.)
	___	9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
	___	7% (24"o.c.)
	___	4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	2.0 in air space; heat flow up	0.780	-----
5.	2X6 in fir framing	-----	5.445
6.	R-11 fiberglass insulation	11.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	14.130	7.795
		R_c	R_f

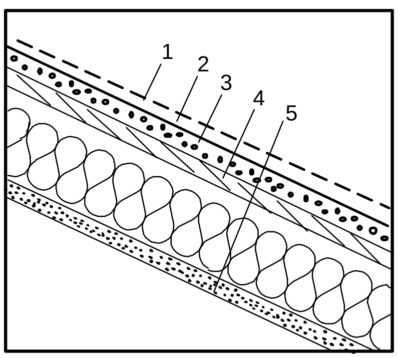
Framing Adjustment Calculation:

[(1/14.130) × (1-10/100)] + [(1/7.795) × (10/100)] = **0.077** **Total U-Value**

($1 \div R_c$) ($1-(\text{Fr.\%} \div 100)$) ($1 \div R_f$) ($\text{Fr.\%} \div 100$)

1/0.077 ($1 \div$ Total U-Value) = 12.987 **Total R-Value**

Reference Name: R.11.2X6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 11.800; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

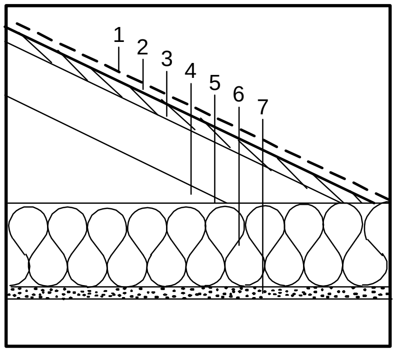
List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	0.75 in Polyisocyanurate	5.250
4.	0.625 in Plywood	0.780
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.071** **Total U-Value**

1/0.071 ($1 \div$ Total U-Value) = 14.060 **Total R-Value**

Reference Name: R.11.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ____ Floor
- ____ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

Wall:
- ____ 15% (16"o.c.)
- ____ 12% (24"o.c.)
- ____ 9% (48"o.c.)

Floor/Ceiling
- ____ 10% (16"o.c.)
- ✓ 7% (24"o.c.)
- ____ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		**R-Value Cavity (R_c)**	**Frame (R_f)**
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-11 fiberglass insulation	11.000	-----
6.	2X4 in fir framing	-----	3.465
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	14.150	6.615
		R_c	R_f

Framing Adjustment Calculation:

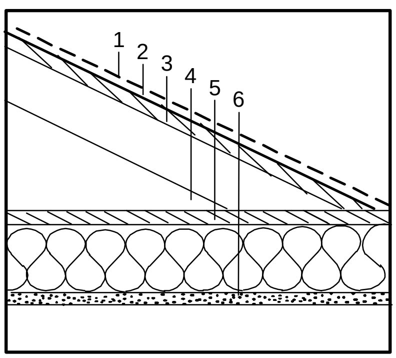
$$[(\underset{1\div R_c}{1/14.150}) \times (\underset{1-(\text{Fr.\%}\div 100)}{1-7/100})] + [(\underset{1\div R_f}{1/6.615}) \times (\underset{\text{Fr.\%}\div 100}{7/100})] = 0.077$$

Total U-Value

$$\underset{1\div \text{Total U-Value}}{1/0.077} = 12.987$$

Total R-Value

Reference Name: R.11.2X4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ____ Floor
- ____ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 11.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	0.75 in Polyisocyanurate	5.250
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.610

Calculation:

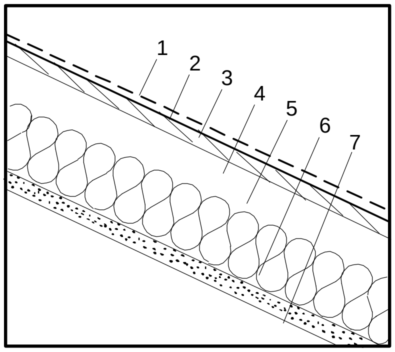
From EZFRAME = 0.069

Total U-Value

$$\underset{1\div \text{Total U-Value}}{1/0.069} = 14.500$$

Total R-Value

Reference Name: R.13.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ____ Floor
- ____ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:	____	15% (16"o.c.)
	____	12% (24"o.c.)
	____	9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
	____	7% (24"o.c.)
	____	4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	2.0 in air space; heat flow up	0.780	-----
5.	2X6 in fir framing	-----	5.445
6.	R-13 fiberglass insulation	13.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	16.130	7.795
		R_c	R_f

Framing Adjustment Calculation:

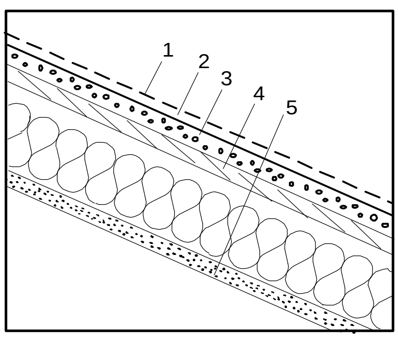
[(1/16.130) × (1-10/100)] + [(1/7.795) × (10/100)] = **0.069**

($1 \div R_c$) × (1-(Fr.% ÷100)) + ($1 \div R_f$) × (Fr.% ÷100)

Total U-Value

1/0.069 (1÷Total U-Value) = 14.493 **Total R-Value**

Reference Name: R.13.2X6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ____ Floor
- ____ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size:
- Actual Depth: 6.00
- Actual Width: 1.625

Cavity Insulation:
- R-value: 13.800
- Knock-out (%): 15.000
- Web Thickness: 0.060

Insulation Tape R-value:
- Interior Flange: ____
- Exterior Flange: ____

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	1.00 in polyisocyanurate	7.000
4.	0.50 in plywood	0.630
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

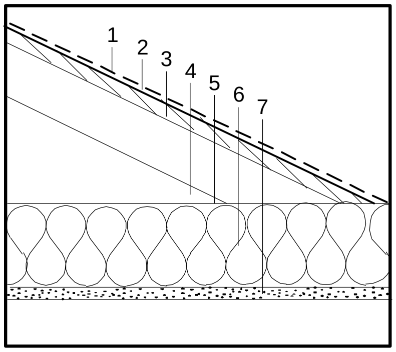
Calculation:

From EZFRAME = **0.062**

Total U-Value

1/0.062 (1÷Total U-Value) = 16.130 **Total R-Value**

Reference Name: **R.13.2x4.24**



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

Wall:
- ___ 15% (16"o.c.)
- ___ 12% (24"o.c.)
- ___ 9% (48"o.c.)

Floor/Ceiling
- ___ 10% (16"o.c.)
- ✓ 7% (24"o.c.)
- ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		**R-Value Cavity (R_c)**	**R-Value Frame (R_f)**
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-13 fiberglass insulation	13.000	-----
6.	2X4 in fir framing	-----	3.465
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	16.150	6.615
		R_c	R_f

Framing Adjustment Calculation:

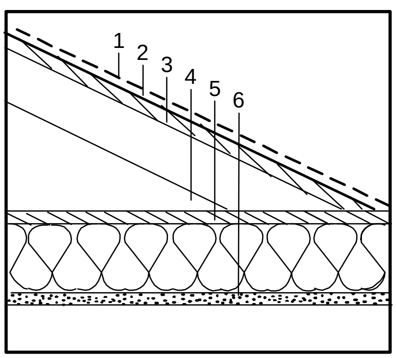
$$[(\underset{1 \div R_c}{1/16.150}) \times (\underset{1-(Fr.\% \div 100)}{1-7/100})] + [(\underset{1 \div R_f}{1/6.615}) \times (\underset{Fr.\% \div 100}{7/100})] = 0.069$$

Total U-Value = **0.069**

$$\underset{1 \div \text{Total U-Value}}{1/0.069} = 14.492$$

Total R-Value = 14.492

Reference Name: **R.13.2X4.24**



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size:
- Actual Depth: 3.625
- Actual Width: 1.625

Cavity Insulation:
- R-value: 13.000
- Knock-out (%): 15.000
- Web Thickness: 0.060

Insulation Tape R-value:
- Interior Flange: ___
- Exterior Flange: ___

List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	0.75 in Polyisocyanurate	5.250
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.610

Calculation:

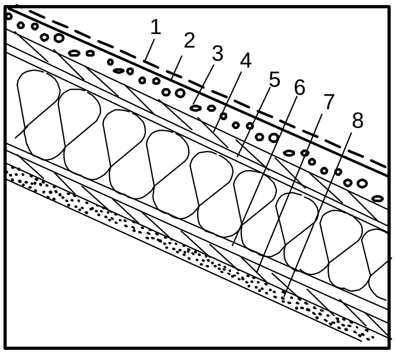
From EZFRAME = **0.066**

Total U-Value = **0.066**

$$\underset{1 \div \text{Total U-Value}}{1/0.066} = 15.100$$

Total R-Value = 15.100

Reference Name: RP.14.2x4.48



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 48 "o.c.

Framing Percentage: (check one)

Wall: ___ 15% (16"o.c.), ___ 12% (24"o.c.), ___ 9% (48"o.c.)

Floor/Ceiling: ___ 10% (16"o.c.), ___ 7% (24"o.c.), ✓ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components / **R-Value**

		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	7/8 in furring channel	0.800	0.800
5.	2X4 in fir framing	-----	3.465
6.	3 5/8 in EPS foam insulation	13.956	-----
7.	7/8 in furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	18.226	7.735
		R_c	R_f

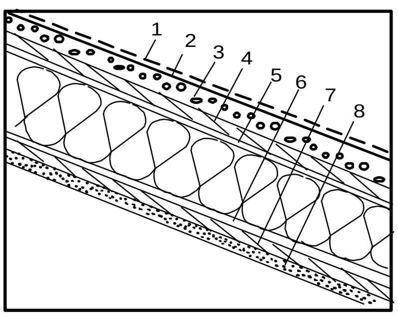
Framing Adjustment Calculation:

[(1/18.226) × (1-4/100)] + [(1/7.735) × (4/100)] = **0.058** **Total U-Value**

($1 \div R_c$) × (1-(Fr.% ÷100)) + ($1 \div R_f$) × (Fr.% ÷100)

1/0.058 (1÷Total U-Value) = 17.288 **Total R-Value**

Reference Name: RP.14.2x4.48



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 48 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 14.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components / **R-Value**

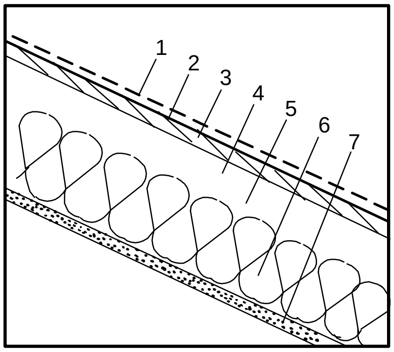
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building paper	0.060
3.	3/4 in polyisocyanurate	5.250
4.	3/8 in plywood	0.470
5.	7/8 in furring channel	0.800
6.	7/8 in furring channel	0.800
7.	3/8 in plywood	0.800
8.	1/2 in gypsum or plaster board	0.470
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.055** **Total U-Value**

1/0.055 (1÷Total U-Value) = 18.130 **Total R-Value**

Reference Name: **R.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 8		
Framing Spacing:	16	"o.c.	
Framing Percentage: (check one)	Wall:		15% (16"o.c.)
			12% (24"o.c.)
			9% (48"o.c.)
	Floor/Ceiling	✓	10% (16"o.c.)
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

	Component	Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	1.0 in air space; heat flow up	0.760	-----
5.	2X8 in fir framing	-----	7.175
6.	R-19 fiberglass insulation	19.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	22.110	9.528
		R_c	R_f

Framing Adjustment Calculation:

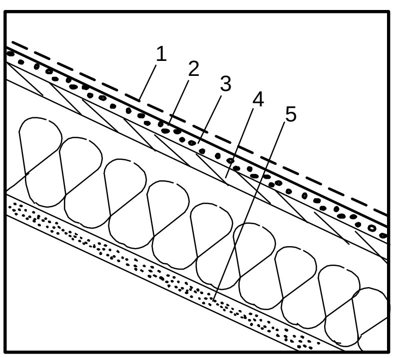
$$[(1/22.110) \times (1-10/100)] + [(1/9.528) \times (10/100)] = 0.051$$

(1÷R_c) × (1-(Fr.% ÷100)) + (1÷R_f) × (Fr.% ÷100)

0.051 Total U-Value

1/0.051 (1÷Total U-Value) = 19.608 **Total R-Value**

Reference Name: **R.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	8.000
	Actual Width	1.625
Cavity Insulation:	R-value	19.800
	Knock-out (%)	15.00
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

List of Construction Components

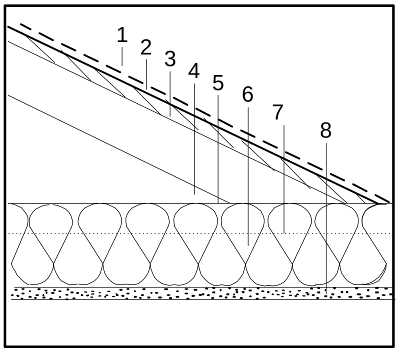
	Component	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building Paper	0.060
3.	1.25 in Polyisocyanurate	8.750
4.	0.5 in plywood	0.630
5.	0.50 in Gypsum board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.051 Total U-Value**

1/0.051 (1÷Total U-Value) = 19.760 **Total R-Value**

Reference Name: R.19.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
	✓	7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

	List of Construction Components	R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-8 fiberglass insulation	8.000	8.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	------	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	22.150	14.615
		R_c	R_f

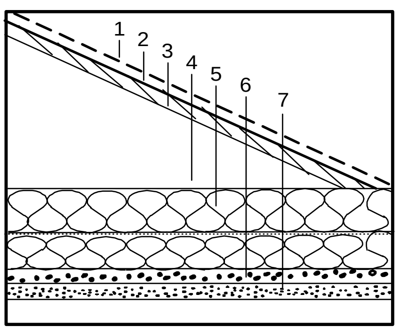
Framing Adjustment Calculation:

[(1/22.15) × (1-7/100)] + [(1/14.615) × (7/100)] = **0.047** **Total U-Value**

($1 \div R_c$) × (1-(Fr.% ÷100)) + ($1 \div R_f$) × (Fr.% ÷100)

1/0.047 (1÷Total U-Value) = 21.277 **Total R-Value**

Reference Name: R.19.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 11.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

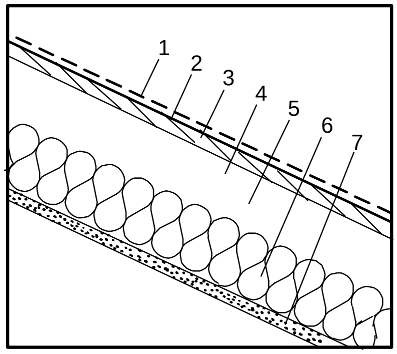
	List of Construction Components	R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Roofing	0.150
2.	Building paper (felt)	0.060
3.	0.625 in Plywood	0.780
4.	3.5 in Air, Ceiling	0.800
5.	R-8 fiberglass insulation	8.000
6.	3/4 in polyisocyanurate	5.250
7.	0.50 in Gypsum board	0.450
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = **0.044** **Total U-Value**

1/0.044 (1÷Total U-Value) = 22.670 **Total R-Value**

Reference Name: **R.22.2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 10
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	0.875 in stucco	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	3.5" & greater air space; heat sidways	0.620	0.620
4.	2x4 in fir framing	0.790	-----
5.	0.50 in gypsum or plaster board	-----	9.158
6.		22.000	-----
7.		0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	25.140	11.058
		R_c	R_f

Framing Adjustment Calculation:

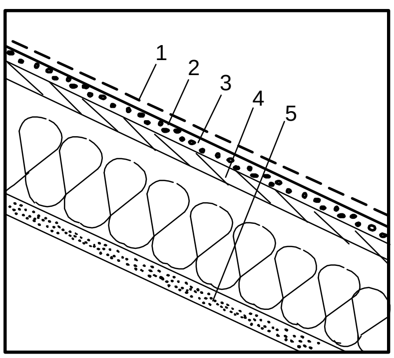
$$[(\underset{1\div R_c}{1/25.14}) \times (\underset{1-(Fr.\%\div 100)}{1\text{-}10/100})] + [(\underset{1\div R_f}{1/11.058}) \times (\underset{Fr.\%\div 100}{10/100})] = 0.045$$

Total U-Value 0.045

$$\underset{1\div \text{Total U-Value}}{1/0.045} = 22.22$$

Total R-Value 22.22

Reference Name: **R.22.2x10.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.

Framing Size:	Actual Depth	10.000
	Actual Width	1.625
Cavity Insulation:	R-value	22.800
	Knock-out (%)	15.000
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Paper	0.440
2.	Building paper (felt)	0.060
3.	1.50 in polyisocyanurate	10.500
4.	0.50 in Plywood	0.630
5.	0.50 in gypsum or plaster board	0.450
6.		
7.		
	Inside Surface Air Film	0.620

Calculation:

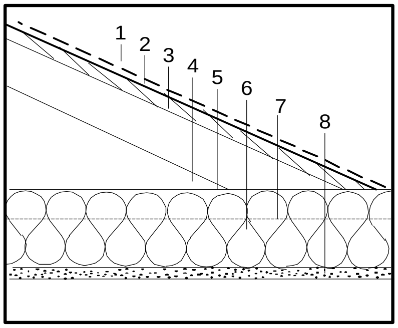
From EZFRAME = 0.044

Total U-Value 0.044

$$\underset{1\div \text{Total U-Value}}{1/0.044} = 22.660$$

Total R-Value 22.660

Reference Name: R.22.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one) ___ Floor ___ Wall ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)
Wall: ___ 15% (16"o.c.) ___ 12% (24"o.c.) ___ 9% (48"o.c.)
Floor/Ceiling: ___ 10% (16"o.c.) ✓ 7% (24"o.c.) ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle rofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space	0.800	0.800
5.	R-11 fiberglass insulation	11.000	11.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	25.150	17.615
		R_c	R_f

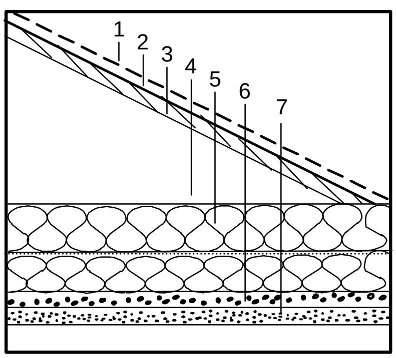
Framing Adjustment Calculation:

$$\left[\left(\frac{1}{25.15}\right)_{1\div R_c} \times \left(1-\frac{7}{100}\right)_{1-(\text{Fr.\%}\div 100)}\right] + \left[\left(\frac{1}{17.615}\right)_{1\div R_f} \times \left(\frac{7}{100}\right)_{\text{Fr.\%}\div 100}\right] = 0.041$$

Total U-Value = **0.041**

$1/0.041$ (1÷Total U-Value) = 24.390 **Total R-Value**

Reference Name: R.22.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one) ___ Floor ___ Wall ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size: Actual Depth 3.625; Actual Width 1.625

Cavity Insulation: R-value 11.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components

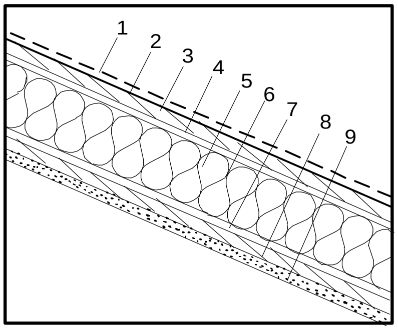
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle rofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space	0.800
5.	R-11 fiberglass insulation	11.000
6.	0.75 in Polyisocyanurate	5.250
7.	0.50 in Gypsum Board	0.450
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = **0.039** **Total U-Value**

$1/0.039$ (1÷Total U-Value) = 25.500 **Total R-Value**

Reference Name: RP.22.2x6.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 48 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling		10% (16"o.c.)
		7% (24"o.c.)
	✓	4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.800
4.	0.875 in furring channel	0.800	0.800
5.	5 5/8 in EPS foam insulation	21.656	-----
6.	2X6 in fir framing	-----	5.445
7.	0.875 in furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	25.926	10.045
		R_c	R_f

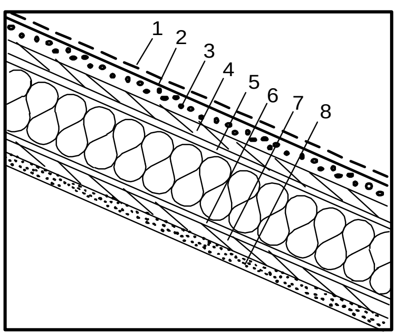
Framing Adjustment Calculation:

$$[(\underset{1 \div R_c}{1/25.926}) \times (\underset{1-(Fr.\% \div 100)}{1-4/100})] + [(\underset{1 \div R_f}{1/10.045}) \times (\underset{Fr.\% \div 100}{4/100})] = 0.041$$

Total U-Value = **0.041**

$\underset{1 \div \text{Total U-Value}}{1/0.041}$ = 24.384 **Total R-Value**

Reference Name: RP.22.2x6.48



Sketch of Construction Assembly

Assembly Type: (check one)

	Floor
	Wall
✓	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 48 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 22.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components

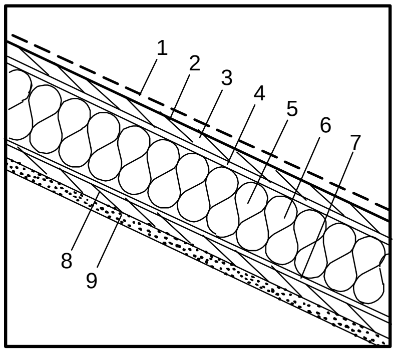
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building paper (felt)	0.060
3.	1.00 in polyisocyanurate	7.000
4.	0.375 in Plywood	0.470
5.	0.875 in furring channel	0.800
6.	0.875 in furring channel	0.800
7.	0.375 in Plywood	0.470
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.039** **Total U-Value**

$\underset{1 \div \text{Total U-Value}}{1/0.039}$ = 25.460 **Total R-Value**

Reference Name: RP.28.2x8.48



Sketch of Construction Assembly

Assembly Type: (check one)
- ____ Floor
- ____ Wall
- ✓ Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 8
Framing Spacing: 48 "o.c.
Framing Percentage: (check one)
- Wall: ____ 15% (16"o.c.)
- ____ 12% (24"o.c.)
- ____ 9% (48"o.c.)
- Floor/Ceiling ____ 10% (16"o.c.)
- ____ 7% (24"o.c.)
- ✓ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		**R-Value** Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 in furring channel	0.800	0.800
5.	7 3/8 in EPS foam insulation @ R-3.85/in	28.394	-----
6.	2X8 in fir framing	-----	7.178
7.	0.875 in furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	32.664	11.448
		R_c	R_f

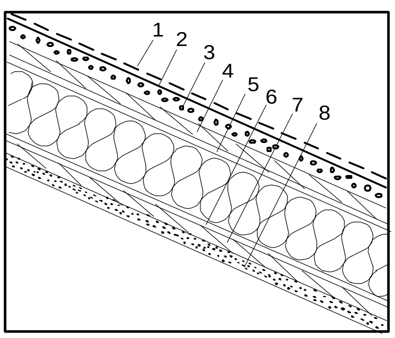
Framing Adjustment Calculation:

[(1/32.664) × (1-4/100)] + [(1/11.448) × (4/100)] = **0.033** **Total U-Value**

(1÷R_c) (1-(Fr.% ÷100)) (1÷R_f) (Fr.% ÷100)

1/0.033 (1÷Total U-Value) = 30.410 **Total R-Value**

Reference Name: RP.28.2x8.48



Sketch of Construction Assembly

Assembly Type: (check one)
- ____ Floor
- ____ Wall
- ✓ Ceiling/Roof

Framing Material: Metal
Framing Spacing: 48 "o.c.
Framing Size: Actual Depth 8.000; Actual Width 1.625
Cavity Insulation: R-value 28.394; Knock-out (%) 15.000; Web Thickness 0.060
Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

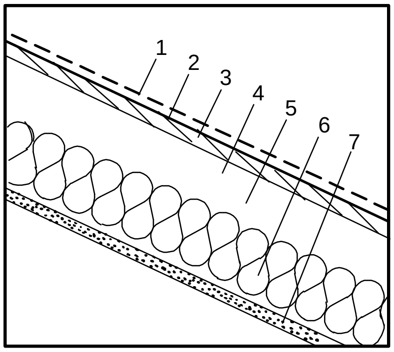
List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building paper (felt)	0.060
3.	1.75 in polyisocyanurate	12.250
4.	0.375 in Plywood	0.470
5.	0.875 in furring channel	0.800
6.	0.875 in furring channel	0.800
7.	0.375 in Plywood	0.470
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.031** **Total U-Value**

1/0.031 (1÷Total U-Value) = 31.940 **Total R-Value**

Reference Name: R.30.2x12.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 12

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:
- ___ 15% (16"o.c.)
- ___ 12% (24"o.c.)
- ___ 9% (48"o.c.)

Floor/Ceiling:
- ✓ 10% (16"o.c.)
- ___ 7% (24"o.c.)
- ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	1.75 in air space; heat fow up	0.780	-----
5.	2X12 in fir framing	-----	11.138
6.	R-30 fiberglass insulation	30.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	33.130	13.488
		R_c	R_f

Framing Adjustment Calculation:

$$[(1/33.130) \times (1\text{-}10/100)] + [(1/13.488) \times (10/100)] = 0.034$$

$1 \div R_c$; $1\text{-}(\text{Fr.\%} \div 100)$; $1 \div R_f$; $\text{Fr.\%} \div 100$

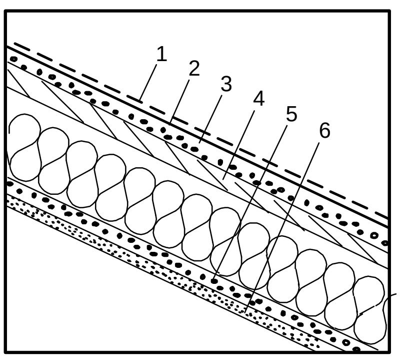
0.034
Total U-Value

$$1/0.034 = 29.412$$

$1 \div$ Total U-Value

Total R-Value 29.412

Reference Name: R.30.2x12.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size:
- Actual Depth 12.00
- Actual Width 1.625

Cavity Insulation:
- R-value 30.8
- Knock-out (%) 15.00
- Web Thickness 0.060

Insulation Tape R-value:
- Interior Flange ___
- Exterior Flange ___

List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building Paper	0.060
3.	1.50 in Polyisocyanurate	10.50
4.	0.50 in plywood	0.62
5.	1.00 in Polyisocyanurate	7.00
6.	0.50 in gypsum or plaster board	0.45
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.032**

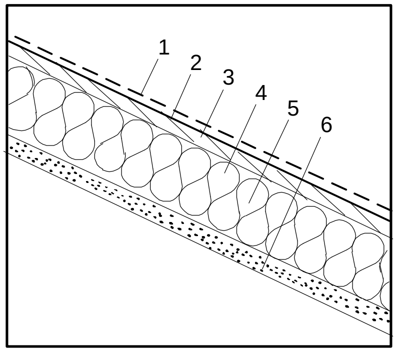
Total U-Value

$$1/0.032 = 31.64$$

$1 \div$ Total U-Value

Total R-Value 31.64

Reference Name: R.30.2x10.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 10
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)

Wall:
- ___ 15% (16"o.c.)
- ___ 12% (24"o.c.)
- ___ 9% (48"o.c.)

Floor/Ceiling:
- ✓ 10% (16"o.c.)
- ___ 7% (24"o.c.)
- ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	2x10 in fir framing	-----	9.158
5.	R-30c fiberglass insulation (8.5'' thkns)	30.000	-----
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	32.350	11.508
		R_c	R_f

Framing Adjustment Calculation:

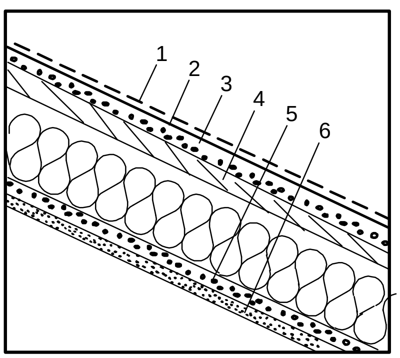
$$[(1/32.350) \times (1-10/100)] + [(1/11.508) \times (10/100)] = 0.036$$

($1 \div R_c$; $1-(\text{Fr.\%} \div 100)$; $1 \div R_f$; $\text{Fr.\%} \div 100$)

0.036 Total U-Value

1/0.036 (1÷Total U-Value) = 27.778 **Total R-Value**

Reference Name: R.30.2x10.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.
Framing Size: Actual Depth 10.00; Actual Width 1.625
Cavity Insulation: R-value 30.80; Knock-out (%) 15.00; Web Thickness 0.060
Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

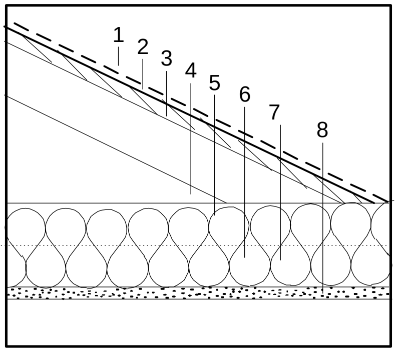
List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	Building Paper	0.060
3.	1.50 in Polyisocyanurate	10.50
4.	0.50 in plywood	0.62
5.	0.75 in Polyisocyanurate	5.25
6.	0.50 in gypsum or plaster board	0.45
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.034 Total U-Value**

1/0.034 (1÷Total U-Value) = 29.220 **Total R-Value**

Reference Name: R.30.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 4
Framing Spacing: 24 "o.c.
Framing Percentage: (check one)

Wall:
- ___ 15% (16"o.c.)
- ___ 12% (24"o.c.)
- ___ 9% (48"o.c.)

Floor/Ceiling:
- ___ 10% (16"o.c.)
- ✓ 7% (24"o.c.)
- ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space	0.800	0.800
5.	R-19 fiberglass insulation	19.000	19.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	33.150	25.615
		R_c	R_f

Framing Adjustment Calculation:

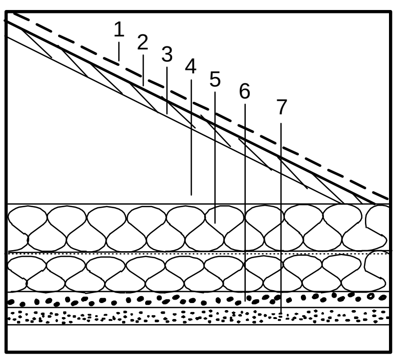
$$[(\underset{1\div R_c}{1/33.150}) \times (\underset{1-(\text{Fr.\%} \div 100)}{1\text{-}7/100})] + [(\underset{1\div R_f}{1/25.615}) \times (\underset{\text{Fr.\%} \div 100}{7/100})] = 0.031$$

Total U-Value

$$\underset{1\div \text{Total U-Value}}{1/0.031} = 32.481$$

Total R-Value

Reference Name: R.30.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal
Framing Spacing: 24 "o.c.
Framing Size:
- Actual Depth 3.625
- Actual Width 1.625

Cavity Insulation:
- R-value 11.00
- Knock-out (%) 15.00
- Web Thickness 0.060

Insulation Tape R-value:
- Interior Flange ___
- Exterior Flange ___

List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle rofing	0.440
2.	Building paper (felt)	0.060
3.	0.50 in plywood	0.630
4.	3.50 in & greater air space	0.800
5.	R-19 fiberglass insulation	19.000
6.	0.75 in Polyisocyanurate	5.250
7.	0.50 in Gypsum Board	0.450
	Inside Surface Air Film	0.680

Calculation:

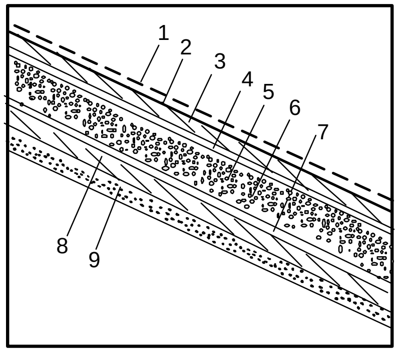
From EZFRAME = 0.030

Total U-Value

$$\underset{1\div \text{Total U-Value}}{1/0.030} = 33.52$$

Total R-Value

Reference Name: RP.35.2x10.48



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 10

Framing Spacing: 48 "o.c.

Framing Percentage: (check one)
- Wall: 15% (16"o.c.)
- 12% (24"o.c.)
- 9% (48"o.c.)
- Floor/Ceiling 10% (16"o.c.)
- 7% (24"o.c.)
- ✓ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.375 in plywood	0.470	0.470
4.	0.875 furring channel	0.800	0.800
5.	4 in EPS foam insulation	35.000	-----
6.	2x10 in fir framing	-----	9.158
7.	0.875 furring channel	0.800	0.800
8.	0.375 in plywood	0.470	0.470
9.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	39.270 (R_c)	13.426 (R_f)

Framing Adjustment Calculation:

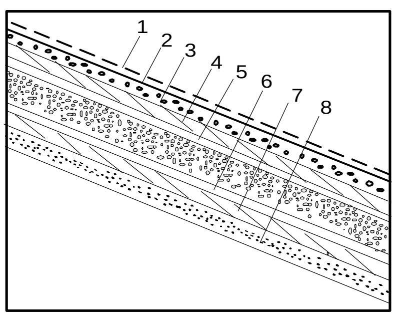
$$\left[\left(\frac{1/39.270}{1\div R_c}\right) \times \left(\frac{1-4/100}{1-(\text{Fr.\%} \div 100)}\right)\right] + \left[\left(\frac{1/13.426}{1\div R_f}\right) \times \left(\frac{4/100}{\text{Fr.\%} \div 100}\right)\right] = 0.027$$

0.027 Total U-Value

$$\frac{1/0.027}{1\div \text{Total U-Value}} = 37.037$$

37.037 **Total R-Value**

Reference Name: RP.35.2x10.48



Sketch of Construction Assembly

Assembly Type: (check one)
- Floor
- Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 48 "o.c.

Framing Size: Actual Depth 10.000; Actual Width 1.625

Cavity Insulation: R-value 35.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt shingle roofing	0.440
2.	Building paper (felt)	0.060
3.	2.25 in polyisocyanurate	15.750
4.	0.375 in plywood	0.470
5.	0.875 in furring channel	0.800
6.	0.875 in furring channel	0.800
7.	0.375 in plywood	0.470
8.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.680

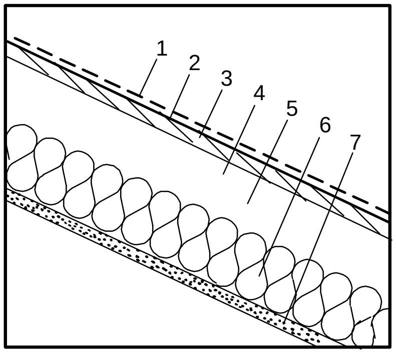
Calculation:

From EZFRAME = **0.026 Total U-Value**

$$\frac{1/0.026}{1\div \text{Total U-Value}} = 38.44$$

38.44 **Total R-Value**

Reference Name: R.38.2x14.16



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 14		
Framing Spacing:	16	"o.c.	
Framing Percentage: (check one)	Wall:		15% (16"o.c.)
			12% (24"o.c.)
			9% (48"o.c.)
	Floor/Ceiling	✓	10% (16"o.c.)
			7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	1.25 in air space; heat flow up	0.760	-----
5.	2X14 in fir framing	-----	13.118
6.	R-38 fiberglass insulation	38.000	-----
7.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	41.110	15.468
		R_c	R_f

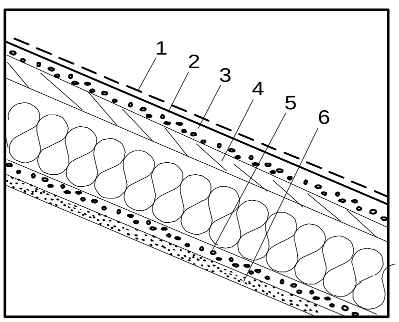
Framing Adjustment Calculation:

[(1/41.110) × (1-10/100)] + [(1/15.468) × (10/100)] = **0.028** **Total U-Value**

($1 \div R_c$; 1-(Fr.% ÷100); $1 \div R_f$; Fr.% ÷100)

1/0.028 (1÷Total U-Value) = 35.714 **Total R-Value**

Reference Name: R.38.2x14.16



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	Metal		
Framing Spacing:	16	"o.c.	
Framing Size:		Actual Depth	14.000
		Actual Width	1.625
Cavity Insulation:		R-value	38.800
		Knock-out (%)	15.00
		Web Thickness	0.060
Insulation Tape R-value:		Interior Flange	
		Exterior Flange	

List of Construction Components

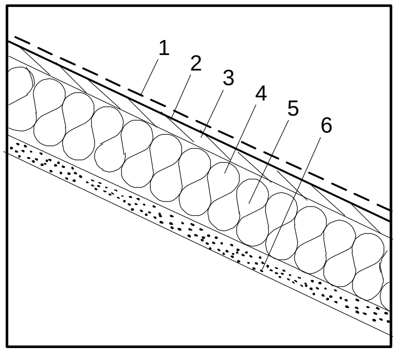
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building paper (felt)	0.060
3.	1.50 in Polyisocyanurate	10.500
4.	0.50 in Plywood	0.630
5.	1.50 in Polyisocyanurate	10.500
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.027** **Total U-Value**

1/0.027 (1÷Total U-Value) = 36.95 **Total R-Value**

Reference Name: R.38.2x12.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 12

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	2X12 in fir framing	-----	11.138
5.	R-38 fiberglass insulation	37.000	-----
6.	0.50 in gypsum or plaster board	0.450	0.450
7.			
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	39.350	13.488
		R_c	R_f

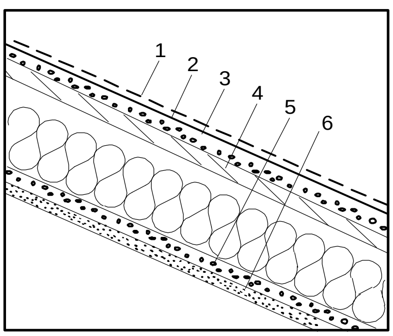
Framing Adjustment Calculation:

[(1/39.350) × (1-10/100)] + [(1/13.488) × (10/100)] = **0.030** **Total U-Value**

$1 \div R_c$; 1-(Fr.% ÷100); $1 \div R_f$; Fr.% ÷100

1/0.030 (1÷Total U-Value) = 33.333 **Total R-Value**

Reference Name: R.38.2x12.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ___ Floor
- ___ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 12.000; Actual Width 1.625

Cavity Insulation: R-value 38.800; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components

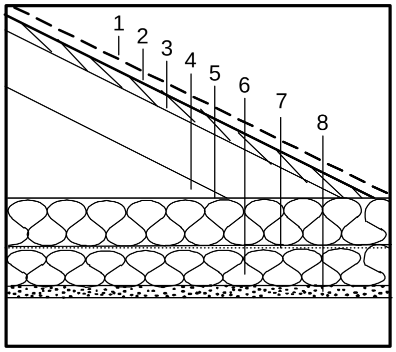
		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building paper (felt)	0.060
3.	1.50 in polyisocyanurate	10.50
4.	0.625 in plywood	0.780
5.	1.00 in polyisocyanurate	7.00
6.	0.625 in gypsum or plaster board	0.560
7.		
	Inside Surface Air Film	0.620

Calculation:

From EZFRAME = **0.030** **Total U-Value**

1/0.030 (1÷Total U-Value) = 33.38 **Total R-Value**

Reference Name: R.38.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	Wood		
Framing Size:	2 × 4		
Framing Spacing:	24	"o.c.	
Framing Percentage: (check one)	Wall:		15% (16"o.c.)
			12% (24"o.c.)
			9% (48"o.c.)
	Floor/Ceiling		10% (16"o.c.)
		✓	7% (24"o.c.)
			4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA		

List of Construction Components — **R-Value**

		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-27 fiberglass insulation	27.000	27.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	41.150	33.615
		R_c	R_f

Framing Adjustment Calculation:

[(1/41.150) × (1-7/100)] + [(1/33.615) × (7/100)] = **0.024**

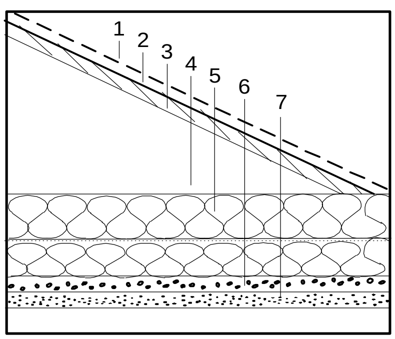
($1 \div R_c$) ($1-(\text{Fr.\%} \div 100)$) ($1 \div R_f$) ($\text{Fr.\%} \div 100$)

Total U-Value

1/0.024 ($1 \div$ Total U-Value) = 41.667

Total R-Value

Reference Name: R.38.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)		Floor	
		Wall	
	✓	Ceiling/Roof	
Framing Material:	Metal		
Framing Spacing:	24	"o.c.	
Framing Size:		Actual Depth	3.625
		Actual Width	1.625
Cavity Insulation:		R-value	11.00
		Knock-out (%)	15.000
		Web Thickness	0.060
Insulation Tape R-value:		Interior Flange	
		Exterior Flange	

List of Construction Components — **R-Value**

		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building paper (felt)	0.060
3.	0.50 in Plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	R-27 fiberglass insulation	27.00
6.	1.00 in polyisocyanurate	7.00
7.	0.50 in gypsum or plaster board	0.450
	Inside Surface Air Film	0.610

Calculation:

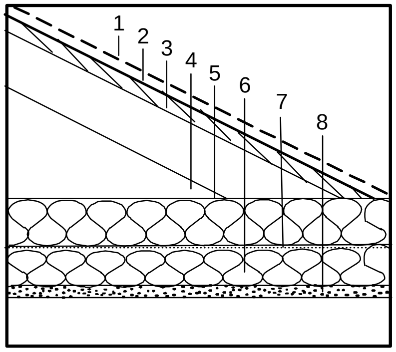
From EZFRAME = **0.023**

Total U-Value

1/0.023 ($1 \div$ Total U-Value) = 43.25

Total R-Value

Reference Name: R.49.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 4	
Framing Spacing:	16	"o.c.
Framing Percentage: (check one)	Wall:	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
	Floor/Ceiling ✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components		**R-Value** Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-38 fiberglass insulation	38.000	38.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	52.150 (R_c)	44.615 (R_f)

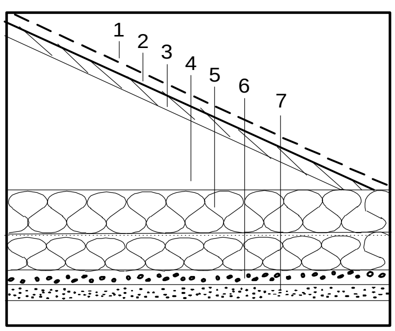
Framing Adjustment Calculation:

[(1/52.150) × (1-10/100)] + [(1/44.615) × (10/100)] = **0.019 Total U-Value**

($1 \div R_c$) × (1-(Fr.% ÷100)) + ($1 \div R_f$) × (Fr.% ÷100)

1/0.019 (1÷Total U-Value) = 52.632 **Total R-Value**

Reference Name: R.49.2x4.16



Sketch of Construction Assembly

Assembly Type: (check one)		Floor
		Wall
	✓	Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	3.625
	Actual Width	1.625
Cavity Insulation:	R-value	11.00
	Knock-out (%)	15.00
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

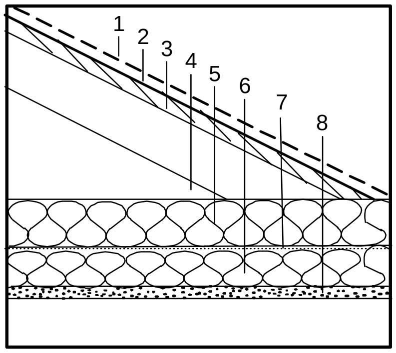
List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	Asphalt shingle	0.440
2.	0.50 in plywood	0.630
3.	3.50 in air space	0.800
4.	R-38 fiberglass insulation	38.00
5.	1.00 in polyisocyanurate	7.000
6.	0.50 in gypsum or plaster board	0.450
7.		
	Inside Surface Air Film	0.610

Calculation:

From EZFRAME = **0.019 Total U-Value**

1/0.019 (1÷Total U-Value) = 53.02 **Total R-Value**

Reference Name: R.49.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ______ Floor
- ______ Wall
- ✓ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 4

Framing Spacing: 24 "o.c.

Framing Percentage: (check one)

Wall:
- ______ 15% (16"o.c.)
- ______ 12% (24"o.c.)
- ______ 9% (48"o.c.)

Floor/Ceiling
- ______ 10% (16"o.c.)
- ✓ 7% (24"o.c.)
- ______ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Asphalt shingle roofing	0.440	0.440
2.	Building paper (felt)	0.060	0.060
3.	0.50 in plywood	0.620	0.620
4.	3.50 in & greater air space; heat flow up	0.800	0.800
5.	R-38 fiberglass insulation	38.000	38.000
6.	R-11 fiberglass insulation	11.000	-----
7.	2X4 in fir framing	-----	3.465
8.	0.50 in gypsum or plaster board	0.450	0.450
	Inside Surface Air Film	0.610	0.610
	Total Unadjusted R-Values:	52.150	44.615
		R_c	R_f

Framing Adjustment Calculation:

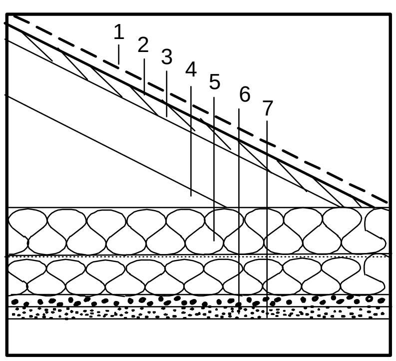
$$[(\underbrace{1/52.15}_{1 \div R_c}) \times (\underbrace{1-7/100}_{1-(\text{Fr.\%} \div 100)})] + [(\underbrace{1/44.615}_{1 \div R_f}) \times (\underbrace{7/100}_{\text{Fr.\%} \div 100})] = 0.019$$

0.019 **Total U-Value**

$$\underbrace{1/0.019}_{1 \div \text{Total U-Value}} = 52.632$$

Total R-Value

Reference Name: R.49.2x4.24



Sketch of Construction Assembly

Assembly Type: (check one)
- ______ Floor
- ______ Wall
- ✓ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 24 "o.c.

Framing Size:
- Actual Depth: 3.625
- Actual Width: 1.625

Cavity Insulation:
- R-value: 11.00
- Knock-out (%): 15.00
- Web Thickness: 0.060

Insulation Tape R-value:
- Interior Flange: ______
- Exterior Flange: ______

List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	Asphalt Shingle	0.440
2.	Building paper (felt)	0.060
3.	0.50 in Plywood	0.630
4.	3.50 in & greater air space; heat flow up	0.800
5.	R-38 fiberglass insulation	38.000
6.	0.25 in Polyisocyanurate	1.750
7.	0.75 in gypsum or plaster board	0.680
	Inside Surface Air Film	0.610

Calculation:

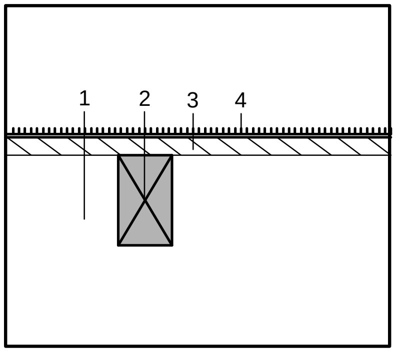
From EZFRAME = **0.018**

Total U-Value

$$\underbrace{1/0.018}_{1 \div \text{Total U-Value}} = 54.250$$

Total R-Value

Reference Name: FC.0.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 6	
Framing Spacing:	16	"o.c.
Framing Percentage: (check one)	Wall:	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
	Floor/Ceiling ✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	2X6 in fir framing	-----	5.445
3.	0.625 in plywood	0.770	0.770
4.	Carpet & Pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	3.940	9.385
		R_c	R_f

Framing Adjustment Calculation:

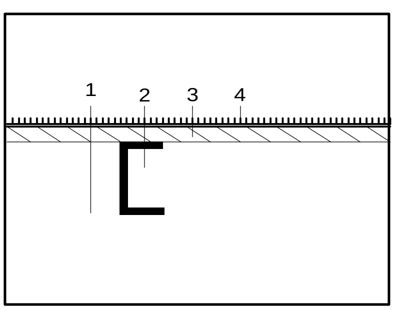
$$[(1/9.940) \times (1\text{-}10/100)] + [(1/15.385) \times (10/100)] = \mathbf{0.097}$$

$1 \div R_c$; 1-(Fr.% ÷100); $1 \div R_f$; Fr.% ÷100

0.097 Total U-Value

1/0.097 (1÷Total U-Value) = 10.309 **Total R-Value**

Reference Name: FC.0.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	0.800
	Knock-out (%)	15.000
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

List of Construction Components

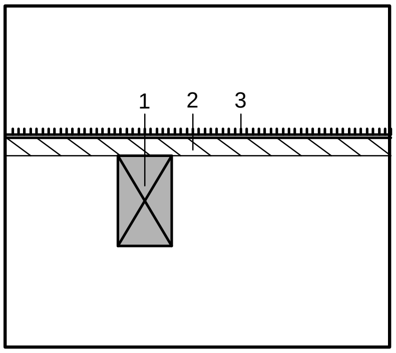
		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	0.625 in plywood	0.780
3.	Carpet & Pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = **0.094 Total U-Value**

1/0.094 (1÷Total U-Value) = 10.680 **Total R-Value**

Reference Name: FX.0.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall: ___ 15% (16"o.c.); ___ 12% (24"o.c.); ___ 9% (48"o.c.)

Floor/Ceiling: ✓ 10% (16"o.c.); ___ 7% (24"o.c.); ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. 2X6 in fir framing	-----	5.445
2. 0.625 in plywood	0.770	0.770
3. Carpet & Pad	2.080	2.080
4.		
5.		
6.		
7.		
Inside Surface Air Film	0.920	0.920
Total Unadjusted R-Values:	3.940	9.385
	R_c	R_f

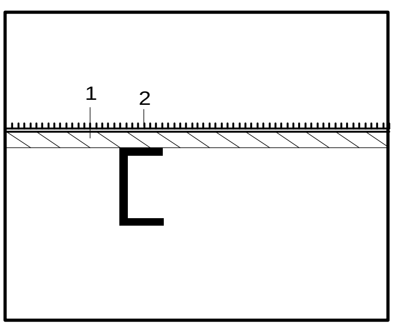
Framing Adjustment Calculation:

[(1/3.940) × (1-10/100)] + [(1/9.385) × (10/100)] = **0.241** **Total U-Value**

(1÷R_c; 1-(Fr.% ÷100); 1÷R_f; Fr.% ÷100)

1/0.241 (1÷Total U-Value) = 4.150 **Total R-Value**

Reference Name: FX.0.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 0.800; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

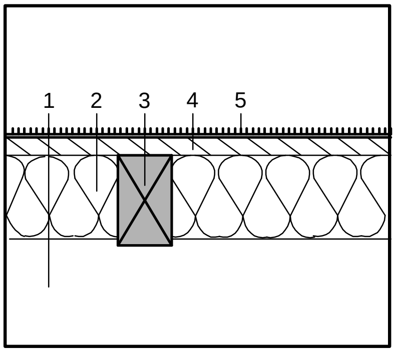
List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 0.625 in plywood	0.780
2. Carpet & pad	2.08
3.	
4.	
5.	
6.	
7.	
Inside Surface Air Film	0.920

Calculation:

From EZFRAME = **0.253** **Total U-Value**

1/0.253 (1÷Total U-Value) = 3.950 **Total R-Value**

Reference Name: FC.11.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)

✓	Floor
	Wall
	Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components		**R-Value** Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-11 fiberglass insulation	11.000	-----
3.	2X6 in fir framing	-----	5.445
4.	0.625 in plywood	0.770	0.770
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	20.940	15.385
		R_c	R_f

Framing Adjustment Calculation:

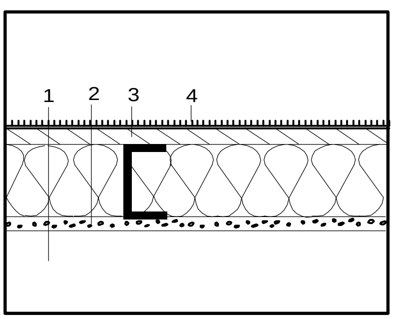
$$[(\underbrace{1/20.940}_{1\div R_c}) \times (\underbrace{1-10/100}_{1-(Fr.\% \div 100)})] + [(\underbrace{1/15.385}_{1\div R_f}) \times (\underbrace{10/100}_{Fr.\% \div 100})] = 0.050$$

Total U-Value

$$\underbrace{1/0.050}_{1\div \text{Total U-Value}} = 20.00$$

Total R-Value

Reference Name: FC.11.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)

✓	Floor
	Wall
	Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 11.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components		**R-Value**
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	0.75 in polyisocyanurate	5.250
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

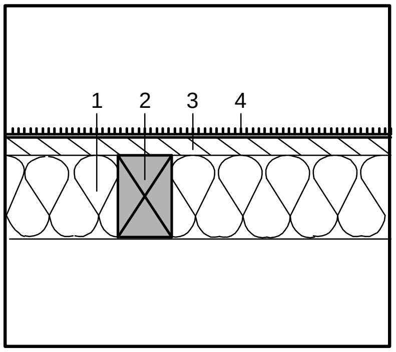
From EZFRAME = 0.048

Total U-Value

$$\underbrace{1/0.048}_{1\div \text{Total U-Value}} = 21.030$$

Total R-Value

Reference Name: FX.11.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ✓ Floor
- ___ Wall
- ___ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:
- ___ 15% (16"o.c.)
- ___ 12% (24"o.c.)
- ___ 9% (48"o.c.)

Floor/Ceiling:
- ✓ 10% (16"o.c.)
- ___ 7% (24"o.c.)
- ___ 4% (48"o.c.)

Wall Weight / sf: NA
(Packages only)

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. R-11 fiberglass insulation	11.000	-----
2. 2X6 in fir framing	-----	5.445
3. 0.625 in Plywood	0.770	0.770
4. Carpet & pad	2.080	2.080
5.		
6.		
7.		
Inside Surface Air Film	0.920	0.920
Total Unadjusted R-Values:	14.940 R_c	9.385 R_f

Framing Adjustment Calculation:

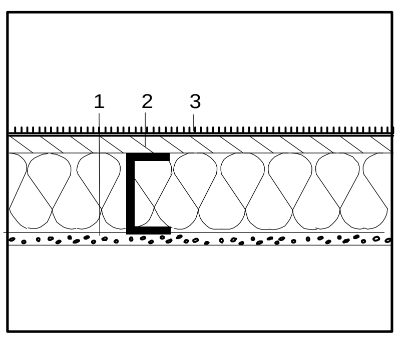
$$\left[\left(\frac{1/14.940}{1 \div R_c}\right) \times \left(\frac{1-10/100}{1-(\text{Fr.}\% \div 100)}\right)\right] + \left[\left(\frac{1/9.385}{1 \div R_f}\right) \times \left(\frac{10/100}{\text{Fr.}\% \div 100}\right)\right] = \mathbf{0.071}$$

Total U-Value

$$\frac{1/0.071}{1 \div \text{Total U-Value}} = 14.085$$

Total R-Value

Reference Name: FX.11.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one)
- ✓ Floor
- ___ Wall
- ___ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 11.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 0.75 in polyisocyanurate	5.250
2. 0.625 in plywood	0.780
3. Carpert & pad	2.080
4.	
5.	
6.	
7.	
Inside Surface Air Film	0.920

Calculation:

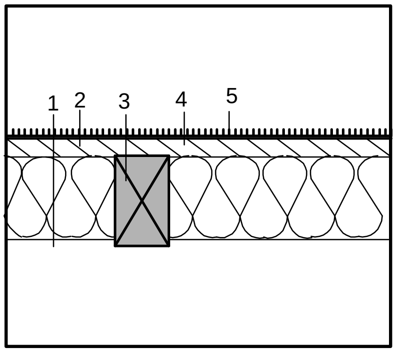
From EZFRAME = **0.071**

Total U-Value

$$\frac{1/0.071}{1 \div \text{Total U-Value}} = 14.16$$

Total R-Value

Reference Name: **FC.13.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 6	
Framing Spacing:	16	"o.c.
Framing Percentage: (check one)	Wall:	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
	Floor/Ceiling ✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-Value of vented crawlspace	6.000	6.000
2.	R-13 fiberglass insulation	13.000	-----
3.	2X6 in fir framing	-----	5.445
4.	0.625 in plywood	0.770	0.770
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	22.940	15.385
		R_c	R_f

Framing Adjustment Calculation:

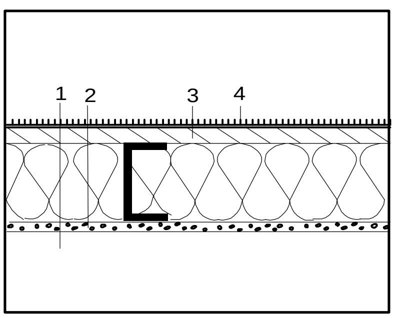
$$[(1/22.94) \times (1\text{-}10/100)] + [(1/15.385) \times (10/100)] = \mathbf{0.046}$$

$1 \div R_c$; 1-(Fr.% ÷100) ; $1 \div R_f$; Fr.% ÷100

Total U-Value

1/0.046 (1÷Total U-Value) = 21.740 **Total R-Value**

Reference Name: **FC.13.2x6.16**



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	6.000
	Actual Width	1.625
Cavity Insulation:	R-value	13.000
	Knock-out (%)	15.000
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-Value of vented crawlspace	6.000
2.	1.00 in polyisocyanurate	7.000
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

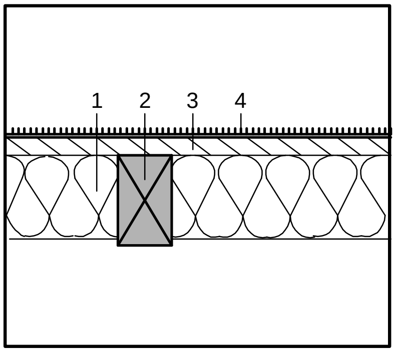
Calculation:

From EZFRAME = **0.043**

Total U-Value

1/0.043 (1÷Total U-Value) = 23.340 **Total R-Value**

Reference Name: FX.13.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 6

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall: ___ 15% (16"o.c.); ___ 12% (24"o.c.); ___ 9% (48"o.c.)

Floor/Ceiling: ✓ 10% (16"o.c.); ___ 7% (24"o.c.); ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. R-13 fiberglass insulation	13.000	-----
2. 2X6 in fir framing	-----	5.445
3. 0.625 in plywood	0.770	0.770
4. Carpet & pad	2.080	2.080
5.		
6.		
7.		
Inside Surface Air Film	0.920	0.920
Total Unadjusted R-Values:	16.940 (R_c)	9.385 (R_f)

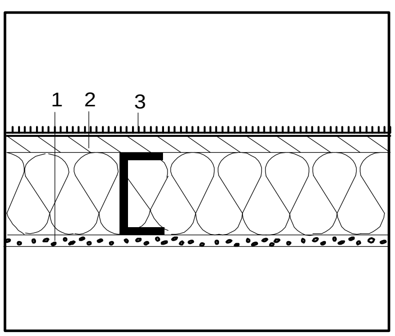
Framing Adjustment Calculation:

[(1/16.940) × (1-10/100)] + [(1/9.385) × (10/100)] = **0.064** **Total U-Value**

(1÷R_c) (1-(Fr.% ÷100)) (1÷R_f) (Fr.% ÷100)

1/0.064 (1÷Total U-Value) = 15.625 **Total R-Value**

Reference Name: FX.13.2x6.16



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 6.000; Actual Width 1.625

Cavity Insulation: R-value 13.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

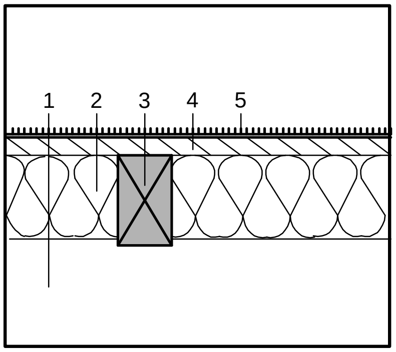
List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 1.00 in polyisocyanurate	7.000
2. 0.625 in plywood	0.780
3. Carpet & pad	2.080
4.	
5.	
6.	
7.	
Inside Surface Air Film	0.920

Calculation:

From EZFRAME = **0.058** **Total U-Value**

1/0.058 (1÷Total U-Value) = 17.340 **Total R-Value**

Reference Name: **FC.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 8

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)
Wall: ___ 15% (16"o.c.); ___ 12% (24"o.c.); ___ 9% (48"o.c.)
Floor/Ceiling: ✓ 10% (16"o.c.); ___ 7% (24"o.c.); ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-19 fiberglass insulation	19.000	-----
3.	7.25 in fir framing	-----	7.178
4.	0.625 in plywood	0.770	0.770
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	28.940	17.118
		R_c	R_f

Framing Adjustment Calculation:

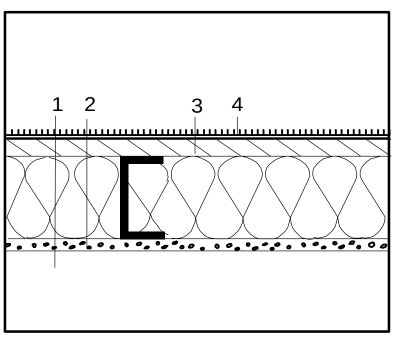
$$[(1/14.535)_{1\div R_c} \times (1\text{-}10/100)_{1-(Fr.\%\div 100)}] + [(1/17.118)_{1\div R_f} \times (10/100)_{Fr.\%\div 100}] = 0.037$$

Total U-Value = 0.037

$$1/0.037_{\,1\div \text{Total U-Value}} = 27.027$$

Total R-Value = 27.027

Reference Name: **FC.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 8.00; Actual Width 1.625

Cavity Insulation: R-value 19.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	1.50 in polyisocyanurate	10.500
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

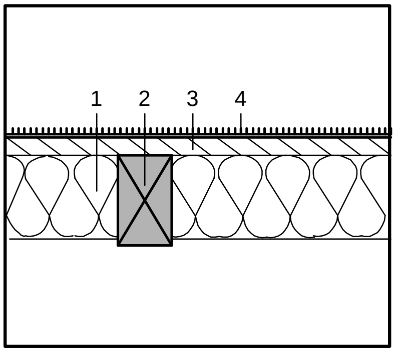
From EZFRAME = 0.035

Total U-Value = 0.035

$$1/0.035_{\,1\div \text{Total U-Value}} = 28.700$$

Total R-Value = 28.700

Reference Name: **FX.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 8

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall:		15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
Floor/Ceiling	✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components

	Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. R-19 fiberglass insulation	19.000	-----
2. 7.25 in fir framing	-----	7.178
3. 0.625 in plywood	0.770	0.770
4. Carpet & pad	2.080	2.080
5.		
6.		
7.		
Inside Surface Air Film	0.920	0.920
Total Unadjusted R-Values:	22.940	11.118
	R_c	R_f

Framing Adjustment Calculation:

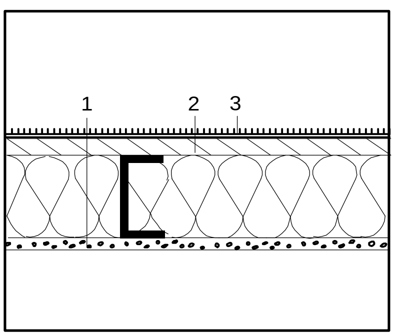
$$[(\frac{1/22.940}{1 \div R_c}) \times (\frac{1-10/100}{1-(Fr.\% \div 100)})] + [(\frac{1/11.118}{1 \div R_f}) \times (\frac{10/100}{Fr.\% \div 100})] = 0.049$$

Total U-Value

$$\frac{1/0.049}{1 \div \text{Total U-Value}} = 20.408$$

Total R-Value

Reference Name: **FX.19.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; ___ Wall; ___ Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 8.00; Actual Width 1.625

Cavity Insulation: R-value 19.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components

	R-Value
Outside Surface Air Film	0.170
1. 1.25 in polyisocyanurate	8.750
2. 0.625 in plywood	0.780
3. Carpet & pad	2.080
4.	
5.	
6.	
7.	
Inside Surface Air Film	0.920

Calculation:

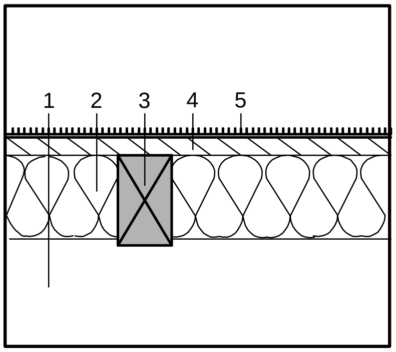
From EZFRAME = **0.048**

Total U-Value

$$\frac{1/0.048}{1 \div \text{Total U-Value}} = 20.950$$

Total R-Value

Reference Name: FC.21.2x8.16



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 8	
Framing Spacing:	16	"o.c.
Framing Percentage: (check one)	Wall:	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
	Floor/Ceiling ✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

	List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-21 fiberglass insulation	21.000	-----
3.	7.25 in fir framing	-----	7.178
4.	0.625 in plywood	0.770	0.770
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	30.940	17.118
		R_c	R_f

Framing Adjustment Calculation:

[(1/30.940) × (1-10/100)] + [(1/17.118) × (10/100)] = **0.035**

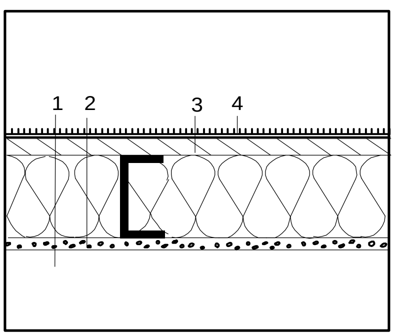
$1 \div R_c$ 1-(Fr.% ÷100) $1 \div R_f$ Fr.% ÷100

Total U-Value

1/0.035 = 28.571

1÷Total U-Value   **Total R-Value**

Reference Name: FC.21.2x8.16



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	8.00
	Actual Width	1.625
Cavity Insulation:	R-value	21.000
	Knock-out (%)	15.000
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

	List of Construction Components	**R-Value**
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	1.50 in polyisocyanurate	10.50
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

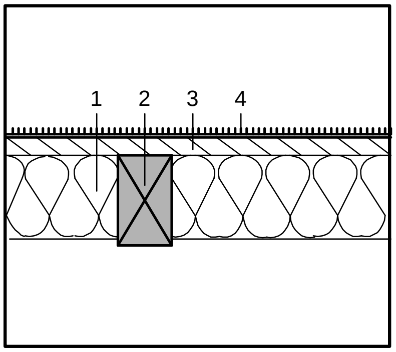
From EZFRAME = **0.034**

Total U-Value

1/0.034 = 29.080

1÷Total U-Value   **Total R-Value**

Reference Name: **FX.21.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- ✓ Floor
- Wall
- Ceiling/Roof

Framing Material: Wood
Framing Size: 2 × 8
Framing Spacing: 16 "o.c.
Framing Percentage: (check one)
- Wall: 15% (16"o.c.)
- 12% (24"o.c.)
- 9% (48"o.c.)
- Floor/Ceiling ✓ 10% (16"o.c.)
- 7% (24"o.c.)
- 4% (48"o.c.)

Wall Weight / sf: NA (Packages only)

List of Construction Components

		R-Value Cavity (R_c)	R-Value Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	R-19 fiberglass insulation	21.000	-----
2.	7.25 in fir framing	-----	7.178
3.	0.625 in plywood	0.780	0.780
4.	Carpet & pad	2.080	2.080
5.			
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	22.950	11.128
		R_c	R_f

Framing Adjustment Calculation:

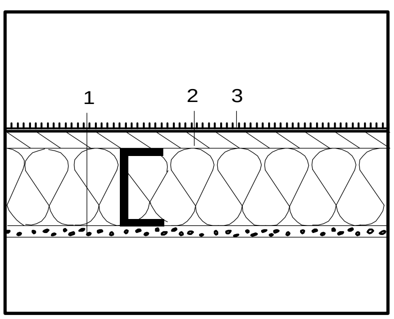
[(1/24.950) × (1-10/100)] + [(1/11.128) × (10/100)] = **0.045**

($1 \div R_c$) (1-(Fr.% ÷100)) ($1 \div R_f$) (Fr.% ÷100)

Total U-Value

1/0.045 (1÷Total U-Value) = 22.220 **Total R-Value**

Reference Name: **FX.21.2x8.16**



Sketch of Construction Assembly

Assembly Type: (check one)
- ✓ Floor
- Wall
- Ceiling/Roof

Framing Material: Metal
Framing Spacing: 16 "o.c.
Framing Size: Actual Depth 8.00; Actual Width 1.625
Cavity Insulation: R-value 21.000; Knock-out (%) 15.000; Web Thickness 0.060
Insulation Tape R-value: Interior Flange ____; Exterior Flange ____

List of Construction Components

		R-Value
	Outside Surface Air Film	0.170
1.	1.50 in polyisocyanurate	10.50
2.	0.625 in plywood	0.780
3.	Carpet & pad	2.080
4.		
5.		
6.		
7.		
	Inside Surface Air Film	0.920

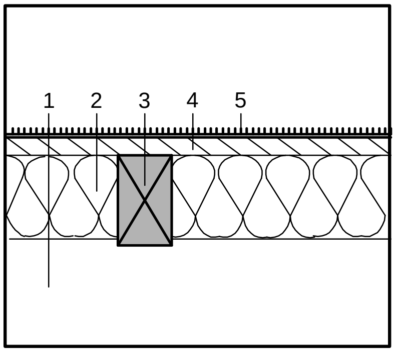
Calculation:

From EZFRAME = **0.043**

Total U-Value

1/0.043 (1÷Total U-Value) = 23.080 **Total R-Value**

Reference Name: FC.30.2x10.16



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Wood	
Framing Size:	2 × 8	
Framing Spacing:	16	"o.c.
Framing Percentage: (check one)	Wall:	15% (16"o.c.)
		12% (24"o.c.)
		9% (48"o.c.)
	Floor/Ceiling ✓	10% (16"o.c.)
		7% (24"o.c.)
		4% (48"o.c.)
Wall Weight / sf: (Packages only)	NA	

List of Construction Components		Cavity (R_c)	Frame (R_f)
	Outside Surface Air Film	0.170	0.170
1.	Effective R-value of vented crawlspace	6.000	6.000
2.	R-30 fiberglass insulation	30.000	-----
3.	9.25 in fir framing	-----	9.158
4.	0.625 in plywood	0.770	0.770
5.	Carpet & pad	2.080	2.080
6.			
7.			
	Inside Surface Air Film	0.920	0.920
	Total Unadjusted R-Values:	39.940	19.098
		R_c	R_f

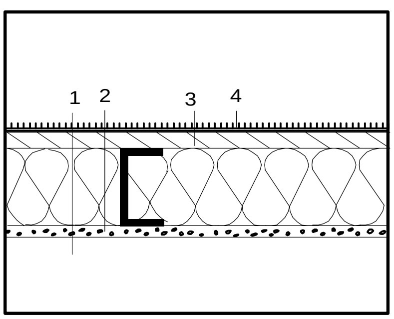
Framing Adjustment Calculation:

[(1/39.940) × (1-10/100)] + [(1/19.098) × (10/100)] = **0.028** **Total U-Value**

($1 \div R_c$) (1-(Fr.% ÷100)) ($1 \div R_f$) (Fr.% ÷100)

1/0.028 (1÷Total U-Value) = 35.714 **Total R-Value**

Reference Name: FC.30.2x10.16



Sketch of Construction Assembly

Assembly Type: (check one)	✓	Floor
		Wall
		Ceiling/Roof
Framing Material:	Metal	
Framing Spacing:	16	"o.c.
Framing Size:	Actual Depth	10.000
	Actual Width	1.625
Cavity Insulation:	R-value	30.000
	Knock-out (%)	15.000
	Web Thickness	0.060
Insulation Tape R-value:	Interior Flange	
	Exterior Flange	

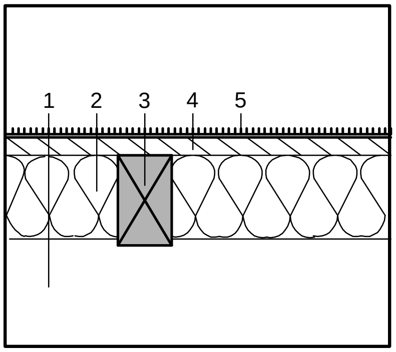
List of Construction Components		R-Value
	Outside Surface Air Film	0.170
1.	Effective R-value of vented crawlspace	6.000
2.	2.50 in polyisocyanurate	17.50
3.	0.625 in plywood	0.780
4.	Carpet & pad	2.080
5.		
6.		
7.		
	Inside Surface Air Film	0.920

Calculation:

From EZFRAME = **0.026** **Total U-Value**

1/0.026 (1÷Total U-Value) = 38.110 **Total R-Value**

Reference Name: FX.30.2x10.16



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; Wall; Ceiling/Roof

Framing Material: Wood

Framing Size: 2 × 8

Framing Spacing: 16 "o.c.

Framing Percentage: (check one)

Wall: ___ 15% (16"o.c.); ___ 12% (24"o.c.); ___ 9% (48"o.c.)

Floor/Ceiling: ✓ 10% (16"o.c.); ___ 7% (24"o.c.); ___ 4% (48"o.c.)

Wall Weight / sf: (Packages only) NA

List of Construction Components	**R-Value** Cavity (R_c)	Frame (R_f)
Outside Surface Air Film	0.170	0.170
1. R-30 fiberglass insulation	30.000	-----
2. 9.25 in fir framing	-----	9.158
3. 0.625 in plywood	0.770	0.770
4. Carpet & pad	2.080	2.080
5.		
6.		
7.		
Inside Surface Air Film	0.920	0.920
Total Unadjusted R-Values:	39.940	19.098
	R_c	R_f

Framing Adjustment Calculation:

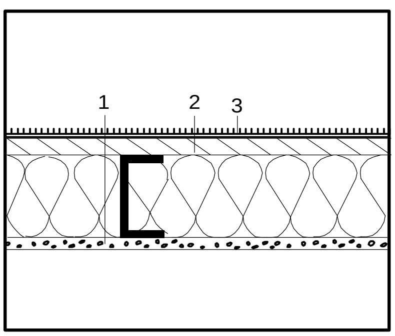
$$[(1/33.940) \times (1-10/100)] + [(1/13.098) \times (10/100)] = 0.034$$

($1 \div R_c$; $1-(\text{Fr.\%} \div 100)$; $1 \div R_f$; $\text{Fr.\%} \div 100$)

0.034
Total U-Value

1/0.034 (1÷Total U-Value) = 29.412 **Total R-Value**

Reference Name: FX.30.2x10.16



Sketch of Construction Assembly

Assembly Type: (check one) ✓ Floor; Wall; Ceiling/Roof

Framing Material: Metal

Framing Spacing: 16 "o.c.

Framing Size: Actual Depth 10.000; Actual Width 1.625

Cavity Insulation: R-value 38.000; Knock-out (%) 15.000; Web Thickness 0.060

Insulation Tape R-value: Interior Flange ___; Exterior Flange ___

List of Construction Components	**R-Value**
Outside Surface Air Film	0.170
1. 2.50 in polyisocyanurate	17.50
2. 0.625 in plywood	0.780
3. Carpet & pad	2.080
4.	
5.	
6.	
7.	
Inside Surface Air Film	0.920

Calculation:

From EZFRAME = **0.031**
Total U-Value

1/0.031 (1÷Total U-Value) = 32.110 **Total R-Value**

EZFrame can be purchased by ordering the following:

Publication No.:	P400-94-002R
Cost:	$14.00
Address:	California Energy Commission Publications, MS-13 P.O. Box 944295 Sacramento, CA 94244-2950

Table B-8A: Fan Motor Efficiencies (< 1 HP)

Nameplate or Brake Horsepower	Standard Fan Motor Efficiency	NEMA* High Efficiency	Premium Efficiency
1/20	40%	...	...
1/12	49%	...	...
1/8	55%	...	...
1/6	60%	...	...
1/4	64%	...	...
1/3	66%	...	...
1/2	70%	76.0%	80.0%
3/4	72%	77.0%	84.0%

NOTE: For default drive efficiencies, See Section 4.2.2

*NEMA - Proposed standard using test procedures.
Minimum NEMA efficiency per test IEEE 112b Rating Method.

TABLE B-8B: Fan Motor Efficiencies (1 HP and over)

	Open Motors				Enclosed Motors			
Number of Poles Synchronous Speed	**2** **3600**	**4** **1800**	**6** **1200**	**8** **900**	**2** **3600**	**4** **1800**	**6** **1200**	**8** **900**
Motor Horsepower								
1	—	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	92.0	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.0	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	—	95.4	95.4	95.0	—
350	95.0	95.4	95.4	—	95.4	95.4	95.0	—
400	95.4	95.4	—	—	95.4	95.4	—	—
450	95.8	95.8	—	—	95.4	95.4	—	—
500	95.8	95.8	—	—	95.4	95.8	—	—

Table B-9: Minimum Mechanical Equipment Efficiencies

Equipment Type		Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Gas Fan Type Central Furnaces		< 225 kBtu/hr		78% AFUE	Note (3)
		> or = 225 kBtu/hr	max. cap. (1)	80% thermal	ANSI Z21.47-83
			min. rated cap. (1)	78% thermal	ANSI Z21.47-83
Oil Furnaces/AC Units		> or = 225 kBtu/hr	both max. and min. rated cap. (1)	81% thermal	U.L. 727-86
Gas Wall Furnaces					Note (4)
	fan type	< or = 42 kBtu/hr		73% AFUE	
		> 42 kBtu/hr		74% AFUE	
	gravity type	< or = 10 kBtu/hr		59% AFUE	
		10 kBtu/hr but < or = 12 kBtu/hr		60% AFUE	
		12 kBtu/hr but < or = 15 kBtu/hr		61% AFUE	
		15 kBtu/hr but < or = 19 kBtu/hr		62% AFUE	
		19 kBtu/hr but < or = 27 kBtu/hr		63% AFUE	
		27 kBtu/hr but < or = 46 kBtu/hr		64% AFUE	
		> 46 kBtu/hr		65% AFUE	
Gas Floor Furnaces		< or = 37 kBtu/hr		56% AFUE	Note (4)
		> 37 kBtu/hr		57% AFUE	
Gas Room Furnaces		< or = 18 kBtu/hr		57% AFUE	Note (4)
		18 kBtu/hr but < or = 20 kBtu/hr		58% AFUE	
		20 kBtu/hr but < or = 27 kBtu/hr		63% AFUE	
		27 kBtu/hr but < or = 46 kBtu/hr		64% AFUE	
		> 46 kBtu/hr		65% AFUE	
Gas Duct Furnaces			max. rated cap. (1)	80% thermal	ANSI Z83.9-1986
			min. rated cap. (1)	75% thermal	
			standby	10 watts	
			LPG standby (2)	147 watts	
Gas Unit Heaters					
	gas-fired		max. rated cap. (1)	80% thermal	ANSI Z83.8-1990
			min. rated cap. (1)	74% thermal	
			standby	10 watts	
			LPG standby (2)	147 watts	
	oil-fired	all sizes	max. & min. rated cap. (1)	81% thermal	UL 731-88

Notes to Table:

1. Provided and allowed by the controls.
2. For units designed expressly for use with liquefied petroleum gases.
3. 10 Code of Federal Regulations Section 430.22 (n) 1989.
4. 10 Code of Federal Regulations Section 430.22 (o) 1989.

(Compiled from Appliance Efficiency and California Building Standards, Titles 20 and 24).

Table B-9: Minimum Mechanical Equipment Efficiencies (Continued)

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Air Conditioners				
Packaged terminal air conditioners				ARI 310-87
Standard rating		95 deg.	Note (2)	
Low temperature rating		82 deg.	Note (3)	
Packaged terminal heat pumps				ARI-380-87
Standard cooling		95 deg.	Note (2)	
Low temperature cooling		82 deg.	Note (3)	
Heating		47 deg. db/43 deg. wb	Note (4)	
All Other Room Air Conditioners				Note (1)
Without reverse cycle/ with louvered sides	<6,000 Btu/hr		8.0 EER	
	6,000 - 7,999 Btu/hr		8.5 EER	
	8,000 - 13,999 Btu/hr		9.0 EER	
	14,000 - 19,999 Btu/hr		8.8 EER	
	>or= 20,000 Btu/hr		8.2 EER	
Without reverse cycle/ without louvered sides				
	<6,000 Btu/hr		8.0 EER	
	>or= 6,000 but <20,000 Btu/hr		8.5 EER	
	>or= 20,000 Btu/hr		8.2 EER	
With reverse cycle/ with louvered sides			8.5 EER	
With reverse cycle/ without louvered sides			8.0 EER	
Computer Room Air Conditioners				ANSI/ASHRAE 127-1988
Air Cooled	< 65 kBtu/hr		8.3 EER	
	>or= 65 < 135 kBtu/hr		7.7 EER	
Water Cooled	< 65 kBtu/hr		8.1 EER	
	>or= 65 < 135 kBtu/hr		8.4 EER	

Notes to Table:

1. 10 CFR Section 430.33(f) (1995).
2. At Standard Rating of 95 deg. F drybulb: EER = 10.0 - (.16xCap/1000). where Cap = rated cooling capacity. If the unit's capacity is less than 7000 Btu/hr, use 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/hr
3. At Low Temperature Rating of 82 deg. drybulb: EER = 12.2 - (.20xCap/1000). If the unit's capacity is less than 7,000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculation. For multi-capacity equipement, the minimum performance shall apply to each capacity step provided and allowed by the controls.
4. At Standard Rating of 47 deg. F drybulb 43 deg. wetbulb: COP = 1.3 + 0.16(EER95 per Note 2).

Table B-9: Minimum Mechanical Equipment Efficiencies (Continued)

Equipement Type		Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Central Air Conditioning Heat Pumps					
Air-Source Heat Pumps					
Split system	cooling	<65 kBtu/hr		10.0 SEER	ARI 240-81
	heating			6.8 HSPF	
Single package	cooling			9.7 SEER	
	heating			6.6 HSPF	
All					
	Cooling	>or= 65, <135 kBtu/hr		8.9 EER	ARI 240-81
				8.3 IPLV	
	Heating		47°F db/43 wb	3.0 COP	
			17°F db/15 wb	2.0 COP	
All					
	Cooling	>or= 135 kBtu/hr <760 kBtu/hr		8.5 EER	ARI 340-86
				7.5 IPLV	
	Heating		47°F	2.9 COP	
			17°F	2.0 COP	
All					
	Cooling	>or= 760 kBtu/hr		8.2 EER	
				7.5 IPLV	
	Heating		47°F	2.9 COP	
			17°F	2.0 COP	
Water Source Heat Pumps					ARI 320-86
	Cooling (1)	< 65 kBtu/hr	85 deg. Water (3)	10.0 EER	
			75 deg. Water (3)	10.2 EER	
		>or= 65, <135 kBtu/hr	85 deg. water (3)	10.5 EER	
	heating (2)		70 deg. water (3)	3.8 COP	
Ground Water Heat Pumps					ARI 325-85
	cooling (1)		70 deg. water (3)	11.0 EER	
			50 deg. water (3)	11.5 EER	
	heating (2)		70 deg. water (3)	3.5 COP	
			50 deg. water (3)	3.0 COP	

Table B-9: Minimum Mechanical Equipment Efficiencies (Continued)

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Air-Cooled Central Air Conditioners				ARI 210-81
Split system	< 65 kBtu/hr		10.0 SEER	
Single package			9.7 SEER	
All	>or= 65,	95 ºF db	8.9 EER	
	< 135 kBtu/hr	80 ºF db	8.3 IPLV	
All	>or= 135,			
	<760 kBtu/hr		8.5 EER	ARI 360-86
			7.5 IPLV	
All	>or= 760 kBtu/hr		8.2 EER	ARI 360-86
			7.5 IPLV	
Evaporatively-Cooled				
Central Air Conditioners				
	< 65 kBtu/hr	95 ºF db/ 75 ºF wb (1)	9.3 EER	
		80 ºF db/ 67 ºF wb (1)	8.5 IPLV	
	> or = 65,			
	< 135 kBtu/hr	95 ºF db/ 75 ºF wb (1)	10.5 EER	
		80 ºF db/ 67 ºF wb (1)	9.7 IPLV	
	> or = 135 kBtu/hr		9.6 EER	ARI 360-86
			9.0 IPLV	CTI 201(86)
Water-Cooled				
Central Air Conditioners				
	<65 kBtu/hr	85 ºF (2)	9.3 EER	
		75 ºF (2)	8.3 IPLV	
	> or = 65, < 135 kBtu/hr	85 ºF (2)	10.5 EER	
	> or = 135 kBtu/hr		9.6 EER	ARI 360-86
			9.0 IPLV	CTI 201(86)
Condensing Units				
Air Cooled	> or = 135 kBtu/hr		9.9 EER	ARI 365-87
			11.0 IPLV	
Water or Evap. Cooled	> or = 135 kBtu/hr		12.9 EER	ARI 365-87
			12.9 IPLV	CTI 201 (86)

Notes to Table:

1. Outdoor condition, dry bulb and wet bulb
2. Entering water temperature.

Table B-9: Minimum Mechanical Equipment Efficiencies (Continued)

Equipment Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Electric Water Chilling Packages				
Water Cooled	< 150 tons		3.8 COP	CTI 201 (86)
			3.9 IPLV	ARI 550-90
				ARI 590-90
	> or = 150 tons			
	but <300 tons		4.2 COP	
			4.5 IPLV	
	> or = 300 tons	Note 1	5.2 COP	
			5.3 IPLV	
		all others	4.7 COP	
			4.8 IPLV	
Air cooled, with condenser	< 150 tons		2.7 COP	ARI 550-90
			2.8 IPLV	ARI 590-90
	> or = 150 tons		2.5 COP	
			2.5 IPLV	
Air cooled, without condenser	All sizes		3.1 COP	ARI 550-90
			3.2 IPLV	ARI 590-90

Notes to Table:

1. With CFC refrigerants with ozone depletion factors greater than those for R-22.

Table B-9: Minimum Mechanical Equipment Efficiencies (Continued)

Equipement Type	Size Category	Sub-Category of Rating Condition	Required Efficiency	Test Standard
Gas Boilers				
Steam Boilers	< 300 kBtu/hr		75% AFUE	10 CFR Section 430.22 (n) (1995)
Other Boilers	< 300 kBtu/hr		80% AFUE	430.22 (n) (1995)
All	>or= 300 kBtu/hr	at both max & min capacity (1)	80% Thermal	ANSI Z21.13-1987
		standby LPG other gases	352 watts (2) 147 watts	
Oil Boilers - All fuels	<300 kBtu/hr		80% AFUE	10 CFR Part 430, Appendix N
Other than Residual Oil	>or= 300 kBtu/hr	at both max & min capacity (1)	83% Combustion	HI Heating Boiler Standard 86 ASME PTC 4.1-64 UL 726-75
Residual oil	>or= 300 kBtu/hr	at both max & min capacity (1)	83% Combustion	HI Heating Boiler Standard 86 ASME PTC 4.1-64

Notes to Table:

1. Provided and allowed by the controls.
2. For boilers designed expressly for use with liquefied petroleum gases.

Table B-9: Minimum Mechanical Equipment Efficiencies (Continued)

Type	Fuel	Input Rating	Volume (gallons)	Input to Vol. Ratio (Btuh/gal)	Thermal Eff. (%)	Standby Loss [1] (%/hr)	Energy Factor [2]
Service Water Heaters							
Storage	Gas	<or = 75,000 Btu/hr	>or = 20				0.62 - (0.0019 x V)
Storage	Gas	> 75,000 Btu/hr <or = 155,000 Btu/hr	All	< 4,000	78%	1.3 + 114/V	
Storage	Gas	> 155.000 Btu/hr	All	< 4,000	78%	1.3 + 95/V	
Storage	Gas	> 155.000 Btu/hr	>or = 10	>or = 4,000	77%	2.3 + 67/V	
Instantaneous	Gas	<or = 200,000 Btu/hr					0.62 - (0.0019 x V)
Instantaneous	Gas	> 200,000 Btu/hr	< 10	>or = 4,000	80%	no requirement	
Instantaneous	Gas	> 200,000 Btu/hr	>or = 10	>or = 4,000	77%	2.3 + 67/V	
All	Electric	<or = 12 kW	>or = 20				0.93 - (0.00132 x V)
Storage	Electric	> 12 kW				0.30 + 27/V	
Storage	Oil	<or = 105,000 Btu/hr	>or = 20				0.59 - (0.0019 X V)
Storage	Oil	105,000 Btu/hr 155,000 Btu/hr		<4,000	78%	1.3 + 114/V	
Storage	Oil	>155,000 Btu/hr		< 4,000	78%	1.3 + 95/V	
Instantaneous	Oil	<or = 210,000 Btu/hr					0.59 - (0.0019 X V)
Instantaneous	Oil	> 210.000 Btu/hr	< 10	>or = 4,000	80%	no requirement	
Instantaneous	Oil	> 210.000 Btu/hr	>or = 10	>or = 4,000	77%	2.3 + 67/V	

(1) V in the Standby Loss equations is "measured" volume.

(2) V in the Energy Factor equations is the "rated" volume.

Table B-10: Illuminance Categories

NOTE: This table is taken from the *Office Lighting American National Standard Practice*, ANSI/IES RP-1, 1993. The table is produced in its entirely, including captions and footnotes. Permission to reprint is pending.

TABLE 3: Currently recommended illuminance categories for lighting design --target maintained values (See Table 4 for Illuminance Values). These recommendations provide a guide for efficient visual performance in office spaces rather than for safety alone. For a tabulation of minimum levels of illumination required for safety, see Table 7.

	Illuminance Category	Veiling Reflectance
Accounting		
(see individual tasks)		
Copied Tasks		
Ditto Copy (6)	E	!
Micro-fiche reader (1)	B	!!
Mimeograph	D	
Photographs, mod. detail	E	!!
Thermal copy, poor copy	F	!
Xerography, 3rd generation (6) and greater	E	
Xerograph	D	
Drafting Tasks		
Drafting: Mylar		
High contrast media; India ink, plastic leads, soft graphite leads	E	!
Low contrast media, hard graphite leads	F	!
Vellum: high contrast	E	!
low contrast	F	
Tracing paper: high contrast	E	!
low contrast	F	
Overlays (2)		
Light Table	C	
Prints: Blue Line	E	
Blueprints	E	
Sepia prints	F	

TABLE 3 (continued)		Illuminace Category	Veiling Reflectance
EDP Tasks			
CRT Screens (1)		B	!!
Impact printer:	good ribbon	D	
	poor ribbon (6)	E	
	2nd carbon and greater (6)	E	
Ink jet printer		D	
Keyboard reading		D	
Machine rooms:	active operations	D	
	tape storage	D	
	machine area	C	
	equipement service (3)	E	
Thermal print		E	!
Filing			
(see individual tasks)			
General and Public Areas			
AV areas		D	
Conference rooms		D	
	(critical seeing, refer to individual tasks)		
Display areas (4)		C	
Duplicating and off-set printing area		D	
Elevators		C	
Escalators		C	
First aid areas		E	
Food service (7)			
Hallways		B	
Janitorial spaces		C	
Libraries (7)			
Lobbies and lounges		C	
Model making		F	
Mail sorting		E	
Mechanical rooms:	operation	B	
	equipment service (3)	E	
Reception area		C	
Rest rooms		C	
Stairs		B	
Utility rooms		B	
Graphic Design and Material			
Color selection (5)		F	
Charting and mapping		F	
Graphs		E	
Keylining		F	
Layout and artwork		F	
Photographs, mod. detail		E	!!
Handwritten Tasks			
#2 pencil and softer leads		D	!
#3 pencil		E	!
#4 pencil and harder leads (6)		F	!
Ball-point pen		D	!
Felt-tip pen		D	
Handwritten carbon copies (6)		E	
Non photographically reproducible colors		F	

TABLE 3 (continued)	Illuminace Category	Veiling Reflectance
Printed Tasks		
6 pt (6) see 2.4	E	!
8 & 10 pt	D	!
Glossy magazines	D	!!
Maps	E	
Newsprint	D	
Typed Originals	D	
Typed 2nd carbon and later (6)	E	
Telephone books	E	

NOTES:

1. Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper light balance.

2. Degradation factors: Overlays--add 1 weighing factor for each overlay
   Used material--estimate additional factors
   See Table 4

3. Only when actual equipment service is in progress. May be achieved by a general lighting system or by localized lighting or by portable equipment.

4. For details on the lighting of display refer to Recommended Practice for Lighting Merchandise Areas. (10)

5. For color matching, the quality of the color of the light source may be important.

6. Designing to higher levels to accommodate poor quality tasks should be undertaken only after it is determined that task quality cannot be improved. If a poor quality task cannot be eliminated, its "time-and-importance" factor should be carefully considered before allowing it to govern the illuminance level selection.

7. See Reference 9.

! Task subject to veiling reflections. Illuminance listed is not an ESI value. Currently, insufficient experience in the use of ESI target values precludes the direct use of Equivalent Sphere Illumination in the present consensus approach recommend illuminance values. Equivalent Sphere Illumination may be used as a tool in determining the effectiveness of controlling veiling reflections and as part of the evaluation of lighting systems.

!! Especially subject to veiling reflectances. It may be necessary to shield the task or to reorient it.

Definition of Merchandising and Associated Service Areas in Stores

NOTE: This table is taken from the *Recommended Practice for Lighting Merchandising Areas*, IES RP-2. The table is produced in its entirety, including captions and footnotes. Permission to reprint is pending.

TABLE 1 -- Currently Recommended Illuminance for Lighting Design in Merchandising and Associated Areas -- Target Maintained Levels

Areas or Tasks	Description	Type of Activity Area*	Lux	Foot-candles
Circulation	Area not used for display or appraisal of merchandise for sales transactions	High activity Medium activity Low activity	300 400 100	30 20 10
Merchandise*** (including showcases & wall displays)	That plane area, horizontal to vertical, where merchandise is displayed and readily accessible for customer examination	High activity Medium activity Low activity	1000 750 300	100 75 30
Show windows				
Daytime lighting				
General			2000	200
Feature			10000	1000
Nighttime lighting				
Main business districts-highly competitive				
General			2000	200
Feature			10000	1000
Secondary business districts or small towns				
General			1000	100
Feature			5000	500
Sales Transactions	Areas used for employee price verification and for recording transactions	Reading of copied, written, printed or EDP information		See Table 2
Support Services	Store spaces where merchandising is a prime consideration	Alteration fitting stock, wrapping and packaging rooms		See Table 2

NOTES:

* One store may encompass all three types within the building: High Activity area -- where merchandise displayed has recognizable usage. Evaluation and viewing time is rapid, and merchandise is sown to attract and stimulate the impulse buying decision; Medium Activity -- where merchandise is familiar in type or usuage, but the customer may require time and/or help in evaluation of quality, usage, or for the decision to buy; and Low Activity -- where merchandise is displayed that is purchased less frequently by the customer, who may be unfamiliar with the inherent quality, design, value or usage. Where assistance and time is necessary to reach a buying decision.

** Maintained on the task or in the area at any time.

*** Lighting levels to be maintained in the plane of the merchandise.

Fig. 2-1. Currently Recommended Illuminance Categories and Illuminance Values for Lighting Design -- Targeted Maintenance Levels.

The tabulation that follows is a consolidated listing of the Society's current illuminance recommendations. This listing is intended to guide the lighting designer in selecting an appropriate illuminance for design and evaluation of lighting systems.

Guidance is provided in two forms: (1), in Parts I, II and III as an *Illuminance Category*, representing a range of illuminances (see page 2-3 for a method of selecting a value within each illuminance range); and (2), in parts IV, V and VI as an *Illuminance Value*. Illuminance Values are given in *lux* with an approximate equivalence in footcandles and as such are intended as *target* (nominal) values with deviations expected. These target values also represent maintained values (see page 2-23).

This table has been divided into the six parts for ease of use. Part I provides a listing of both Illuminance Categories and Illuminance Values for generic types of interior activities and normally is to be used when Illuminance Categories for a specific Area/Activity cannot be found in parts II and III. Parts IV, V and VI provide target maintained Illuminance Values for outdoor facilities sports and recreational areas, and transportation vehicles where special considerations apply as discussed on page 2-4.

In all cases the recommendations in this table are based on the assumption that the lighting will be properly designed to take into account the visual characteristics of the task. See the design information in the particular application sections in this Application Handbook for further recommendations.

II. Commercial, Institutional, Residential and Public Assembly Interiors

Area/Activity	Illuminance Category
Accounting (see **Reading**)	
Air terminals (see Transportation terminals)	
Armories	C[1]
Art galleries (see **Museums**)	
Auditoriums	
Assembly	C[1]
Social activity	B
Banks	
Lobby	
General	C
Writing area	D
Tellers' stations	E[3]
Barber shops and beauty parlors	E
Churches and synagogues	(see page 7-2)[4]
Club and lodge rooms	
Lounge and reading	D
Conference rooms	
Conferring	D
Critical seeing (refer to individual task)	
Court rooms	
Seating area	C
Court activity area	E[3]
Dance halls and discotheques	B
Depots, terminals and stations (see **Transportation terminals)**	
Drafting	
Mylar	
High contrast media; India ink, plastic leads, soft graphite leads	E[3]
Low contrast media; hard graphite leads	F[3]
Vellum	
High contrast	E[3]
Low contrast	F[3]
Tracing paper	
High contrast	E[3]
Low contrast	F[3]
Overlays[5]	
Light table	C
Prints	
Blue line	E
Blueprints	E
Sepia prints	F

NOTE: This table is taken from the Figure 2-2 of the IES Lighting Handbook 1982 Application Volume. Part II of the table is produced in its entirety, with captions and footnotes. Permission to reprint is pending.

Fig. 2-1. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Educational facilities	
Classrooms	
General (see **Reading**)	
Drafting (see **Drafting**)	
Home economics (see **Residences**)	
Science laboratories	E
Lecture rooms	
Audience (see **Reading**)	
Demonstration	F
Music rooms (see **Reading**)	
Shops (see Part III, Industrial Group)	
Sight saving rooms	F
Study halls (see **Reading**)	
Typing (see **Reading**)	
Sports facilities (see Part V, Sports and Recreational Areas)	
Cafeterias (see **Food service facilities**)	
Dormitories (see **Residences**)	
Elevator, freight and passenger	C
Exhibition halls	C[1]
Filing (refer to individual task)	
Financial facilities (see **Banks**)	
Fire halls (see **Municipal buildings**)	
Food service facilities	
Dining areas	
Cashier	D
Cleaning	C
Dining	B[6]
Food displays (see **Merchandising spaces**)	
Kitchen	E
Garages -- parking	(see page 14-28)
Gasoline stations (see **Service stations**)	
Graphic design and material	
Color selection	F[11]
Charting and mapping	F
Graphs	E
Keylining	F
Layout and artwork	F
Photographs, moderate detail	E[13]
Health care facilities	
Ambulance (local)	E
Anesthetizing	E
Autopsy and morgue[17, 18]	
Autopsy, general	E
Autopsy table	G
Morgue, general	D
Museum	E
Cardiac function lab	E
Central sterile supply	
Inspection, general	E
Inspection	F
At sinks	E
Work areas, general	D
Processed storage	D
Corridors[17]	
Nursing areas -- day	C
Nursing areas -- night	B
Operating areas, delivery, recovery, and laboratory suites and service	E
Critical care areas[17]	
General	C
Examination	E
Surgical task lighting	H
Hand washing	F
Cystoscopy room [17,18]	
Dental suite [17]	
General	D
Instrument tray	E
Oral Cavity	H
Prosthetic laboratory, general	D
Prosthetic laboratory, work bench	E
Prosthetic, laboratory, local	F
Recovery room, general	C
Recovery room, emergency examination	E
Dialysis unit, medical[17]	F
Elevators	C
EKG and specimen room[17]	
General	B
On equipment	C
Emergency outpatient[17]	
General	E
Local	F
Endoscopy rooms [17, 18]	
General	E
Peritoneoscopy	D
Culdoscopy	D
Examination and treatment rooms [17]	
General	D
Local	E
Eye surgery[17, 18]	F
Fracture room[17]	
General	E
Local	F
Inhalation therapy	D
Laboratories[17]	
Specimen collecting	E
Tissue laboratories	F
Microscopic reading room	D
Gross specimen review	F
Chemistry rooms	E

Fig. 2-1. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Bacteriology rooms	
General	E
Reading culture plates	F
Hematology	E
Linens	
Sorting soiled linen	D
Central (clean) linen room	D
Sewing room, general	D
Sewing room, work area	E
Linen closet	B
Lobby	C
Locker rooms	C
Medical illustration studio[17, 18]	F
Medical records	E
Nurseries[17]	
General[18]	C
Observation and treatment	E
Nursing stations[17]	
General	D
Desk	E
Corridors, day	C
Corridors, night	A
Medication station	E
Obstetric delivery suite[17]	
Labor rooms	
General	C
Local	E
Birthing room	F
Delivery area	
Scrub, general	F
General	G
Delivery table	(see page 7-19)
Resuscitation	G
Post delivery recovery area	E
Substerilizing room	B
Occupational therapy[17]	
Work area, general	D
Work tables or benches	E
Patients' rooms[17]	
General[18]	B
Observation	A
Critical examination	E
Reading	D
Toilets	D
Pharmacy[17]	
General	E
Alcohol vault	D
Laminar flow bench	F
Night light	A
Parenteral solution room	D
Physical therapy departments	
Gymnasiums	D
Tank rooms	D
Treatment cubicles	D
Postanesthetic recovery room[17]	
General[18]	E
Local	H
Pulmonary function laboratories[17]	E

Area/Activity	Illuminance Category
Radiological suite[17]	
Diagnostic section	
General[18]	A
Waiting area	A
Radiographic/fluoroscopic room	A
Film sorting	F
Barium kitchen	E
Radiation therapy section	
General[18]	B
Waiting area	B
Isotope kitchen, general	E
Isotope kitchen, benches	E
Computerized radiotomography section	
Scanning room	B
Equipment maintenance room	E
Solarium	
General	C
Local for reading	D
Stairways	C
Surgical suite[17]	
Operating room, general[18]	F
Operating table	(see page 7-15)
Scrub room	F
Instruments and sterile supply room	D
Clean up room, instruments	E
Anesthesia	C
Substerilizing room	C
Surgical induction room[17, 18]	E
Surgical holding area[17, 18]	E
Toilets	C
Utility room	D
Waiting areas[17]	
General	C
Local for reading	D
Homes (see **Residences**)	
Hospitality facilities (see **Hotels, food service facilities**)	
Hospitals (see **Health care facilities**)	
Hotels	
Bathrooms, for grooming	D
Bedrooms, for reading	D
Corridors, elevators and stairs	C
Front desk	E[3]
Linen room	
Sewing	F
General	C
Lobby	
General lighting	C
Reading and working areas	D
Canopy (see Part IV, Outdoor Facilities)	
Houses of worship	(see page 7-5)
Kitchens (see **Food service facilities** or **Residences**)	
Libraries	
Reading areas (see **Reading**)	

Fig. 2-1. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Book stacks [vertical 760 millimeters (30 inches) above floor]	
Active stacks	D
Inactive stacks	B
Book repair and binding	D
Cataloging	D[3]
Card files	E
Carrels, individual study areas (see **Reading**)	
Circulation desks	D
Map, picture and print rooms (see **Graphic design and material**)	
Audiovisual areas	D
Audio listening areas	D
Microform areas (see **Reading**)	
Locker rooms	C
Merchandising spaces	
Alteration room	F
Fitting room	
Dressing areas	D
Fitting areas	F
Locker rooms	C
Stock rooms, wrapping and packaging	D
Sales transaction area (see **Reading**)	
Circulating	(see page 8-7)[8]
Merchandise	(see page 8-7)[8]
Feature display	(see page 8-7)[8]
Show windows	(see page 8-7)[8]
Motels (see **Hotels**)	
Municipal buildings -- fire and police	
Police	
Identification records	F
Jail cells and interrogation rooms	D
Fire hall	D
Museums	
Displays of non-sensitive materials	D
Displays of sensitive materials	(see page 7-34)[2]
Lobbies, general gallery areas, corridors	C
Restoration or conservation shops and laboratories	E
Nursing homes (see **Health care facilities**)	
Offices	
Accounting (see **Reading**)	
Audio-visual areas	D
Conference areas (see **Conference rooms**)	
Drafting (see **Drafting**)	
General and private offices (see **Reading**)	
Libraries (see **Libraries**)	
Lobbies, lounges and reception areas	C
Mail sorting	E
Off-set printing and duplicating area	D
Spaces with VDTs	(see page 5-13)

Area/Activity	Illuminance Category
Parking facilities	(see page 14-28)
Post offices (see **Offices**)	
Reading	
Copied tasks	
Ditto copy	E[3]
Micro-fiche reader	B[12, 13]
Mimeograph	D
Photograph, moderate detail	E[13]
Thermal copy, poor copy	F[3]
Xerography	D
Xerography, 3rd generation and greater	E
Electronic data processing tasks	
CRT screens	B[12, 13]
Impact printer	
good ribbon	D
poor ribbon	E
2nd carbon and greater	E
Ink jet printer	D
Keyboard reading	D
Machine rooms	
Active operations	D
Tape storage	D
Machine area	C
Equipment service	E[10]
Thermal print	E
Handwritten tasks	
#2 pencil and softer leads	D[3]
#3 pencil	E[3]
#4 pencil and harder leads	F[3]
Ball-point pen	D[3]
Felt-tip pen	D
Handwritten carbon copies	E
Non photographically reproducible colors	F
Chalkboards	E[3]
Printed tasks	
6 point type	E[3]
8 and 10 point type	D[3]
Glossy magazines	D[13]
Maps	E
Newsprint	D
Typed originals	D
Typed 2nd carbon and later	E
Telephone books	E
Residences	
General lighting	
Conversation, relaxation and entertainment	B
Passage areas	B
Specific visual tasks[20]	
Dining	C
Grooming	
Makeup and shaving	D
Full-length mirror	D

Fig. 2-1. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Handcrafts and hobbies	
Workbench hobbies	
Ordinary tasks	D
Difficult tasks	E
Critical tasks	F
Easel hobbies	E
Ironing	D
Kitchen duties	
Kitchen counter	
Critical seeing	E
Noncritical	D
Kitchen range	
Difficult seeing	E
Noncritical	D
Kitchen sink	
Difficult seeing	E
Noncritical	D
Laundry	
Preparation and tubs	D
Washer and dryer	D
Music study (piano or organ)	
Simple scores	D
Advanced scores	E
Substandard size scores	F
Reading	
In a chair	
Books, magazines and newspapers	D
Handwriting, reproductions and poor copies	E
In bed	
Normal	D
Prolonged serious or critical	E
Desk	
Primary task plane, casual	D
Primary task plane, study	E
Sewing	
Hand sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Machine sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Table games	D

Area/Activity	Illuminance Category
Restaurants (see **Food service facilities**)	
Safety	(see page 2-45)
Schools (see **Educational facilities**)	
Service spaces (see also **Storage rooms**)	
Stairways, corridors	C
Elevators, freight and passenger	C
Toilet and washroom	C
Service stations	
Service bays (see Part III, Industrial Group)	
Sales room (see **Merchandising spaces**)	
Show windows	(see page 8-7)
Stairways (see **Service spaces**)	
Storage rooms (see Part III, Industrial Group)	
Stores (see **Merchandising spaces** and **Show windows**)	
Television	(see Section 11)
Theater and motion picture houses	(see Section 11)
Toilets and washrooms	C
Transportation terminals	
Waiting room and lounge	C
Ticket counters	E
Baggage checking	D
Rest rooms	C
Concourse	B
Boarding area	C

For footnotes, see following page

[1]Include provisions for higher levels for exhibitions.

[2]Specific limits are provided to minimize deterioration effects.

[3]Task subject to veiling reflections. Illuminance listed is not an Equivalent Sphere Illumination (ESI) value. Currently, insufficient experience in the use of ESI target values precludes the direct use of ESI in the present consensus approach to recommend illuminance values. ESI may be used as a tool in determining the effectiveness of controlling veiling reflections and as a part of the evaluation of lighting systems.

[4]Illuminance values are listed based on experience and consensus. Values relate to needs during various religious ceremonies.

[5]Degradation factors: Overlays -- add 2 weighting factor for each overlay; Used material -- estimate additional factors.

[6]Provide higher level over food service or selection areas.

[7]Supplementary illumination as in delivery room must be available.

8Illuminance values developed for various degrees of store area activity.

[9]Or not less than 1/5 the level in the adjacent areas.

[10]Only when actual equipment service is in process. May be achieved by a general lighting system or by localized or portable equipment.

[11]For color matching, the spectral quality of the color of the light source is important.

[12]Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper illuminance.

[13]Especially subject to veiling reflections. It may be necessary to shield the task or to reorient it.

[14]Vertical

[15]Illuminance values may vary widely, depending upon the effect desired, the decorative scheme, and the use made of the room.

[16]Supplementary lighting should be provided in this space to produce the higher levels required for specific seeing tasks involved.

[17]Good to high color rendering capability should be considered in these areas. As lamps of higher luminous efficacy and higher color rendering capability become available and economically feasible, they should be applied in all areas of health care facilities.

[18]Variable (dimming or switching).

[19]Values based on a 25 percent reflectance, which is average for vegetation and typical outdoor surfaces. These figures must be adjusted to specific reflectances of materials lighted for equivalent brightness. Levels give satisfactory brightness patterns when viewed from dimly lighted terraces or interiors. When viewed from dark areas they may be reduced by at least 1/2; or they may be doubled when a high key is desired.

[20]General lighting should not be less than 1/3 of visual task illuminance nor less than 200 lux [20 footcandles].

[21]Industry representatives have established a table of single illuminance values which, in their opinion, can be used in preference to employing reference 6. Illuminance values for specific operations can also be determined using illuminance categories of similar tasks and activities found in this table and the application of the appropriate weighting factors in Fig. 2-3.

[22]Special lighting such that (1) the luminous area is large enough to cover the surface which is being inspected and (2) the luminance is within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low luminance in which the source luminance is the principal factor rather than the illuminance produced at a given point.

[23]Maximum levels -- controlled system.

[24]Additional lighting needs to be provided for maintenance only.

[25]Color temperature of the light source is important for color matching.

[26] Select upper level for high speed conveyor systems. For grading redwood lumber 3000 lux [300 footcandles] is required.

[27]Higher levels from local lighting may be required for manually operated cutting machines.

[28]If color matching is critical, use illuminance category G.

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Power	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Circline						
Fluorescent Circline, Rapid Start (22 W)						
1	FC8T9	1	MAG STD	Magnetic Standard	27	8" OD
Fluorescent Circline, Rapid Start (32 W)						
1	FC12T9	1	MAG STD	Magnetic Standard	45	12" OD
Fluorescent Circline, Rapid Start (40 W)						
1	FC16T9	1	MAG STD	Magnetic Standard	57	16" OD
Fluorescent 2D						
Compact Fluorescent 2D (10W, GR10q-4 Four Pin Base)						
1	CFS10W/GR10q	1	MAG STD	Magnetic Standard	16	3.6" across
1	CFS10W/GR10q	1	ELECT	Electronic	13	
2	CFS10W/GR10q	1	ELECT	Electronic	26	
Compact Fluorescent 2D (16W, GR10q-4 Four Pin Base)						
1	CFS16W/GR10q	1	MAG STD	Magnetic Standard	23	5.5" across
1	CFS16W/GR10q	1	ELECT	Electronic	15	
2	CFS16W/GR10q	1	ELECT	Electronic	30	
Compact Fluorescent 2D (21W, GR10q-4 Four Pin Base)						
1	CFS21W/GR10q	1	MAG STD	Magnetic Standard	31	5.5" across
1	CFS21W/GR10q	1	ELECT	Electronic	21	
2	CFS21W/GR10q	1	ELECT	Electronic	42	
Compact Fluorescent 2D (28W, GR10q-4 Four Pin Base)						
1	CFS28W/GR10q	1	MAG STD	Magnetic Standard	38	8.1" across
1	CFS28W/GR10q	1	ELECT	Electronic	28	
2	CFS28W/GR10q	1	ELECT	Electronic	56	
Compact Fluorescent 2D (38W, GR10q-4 Four Pin Base)						
1	CFS38W/GR10q	1	ELECT	Electronic	37	8.1" across
2	CFS38W/GR10q	1	ELECT	Electronic	74	
Compact Fluorescent Twin (5 W, G23 Two Pin Base - F5TT Lamp)						
1	CFT5W/G23	1	MAG STD	Magnetic Standard	9	4.1" MOL
2	CFT5W/G23	2	MAG STD	Magnetic Standard	18	
Compact Fluorescent Twin (7 W, G23 Two Pin Base - F7TT Lamp)						
1	CFT7W/G23	1	MAG STD	Magnetic Standard	11	5.3" MOL
2	CFT7W/G23	2	MAG STD	Magnetic Standard	22	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Power	Comments
No.	**Designation**	**No.**	**Abbrev.**	**Description**	**Power**	**Comments**
Compact Fluorescent Twin (9 W, G23 Two Pin Base - F9TT Lamp)						
1	CFT9W/G23	1	MAG STD	Magnetic Standard	13	6.5" MOL
2	CFT9W/G23	2	MAG STD	Magnetic Standard	26	
Compact Fluorescent Twin (13 W, GX23 Two Pin Base - F13TT)						
1	CFT13W/GX23	1	MAG STD	Magnetic Standard	17	7.5" MOL
2	CFT13W/GX23	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (9 W, G23-2 Two Pin Base - F9DTT Lamp)						
1	CFQ9W/G23-2	1	MAG STD 120	120 V Magnetic Standard	13	4.4" MOL
2	CFQ9W/G23-2	2	MAG STD 120	120 V Magnetic Standard	26	
Compact Fluorescent Quad (13 W, G24d-1 Two Pin Base - F13DTT Lamp)						
1	CFQ13W/G24d-1	1	MAG STD 120	120 V Magnetic Standard	18	6.0" MOL
2	CFQ13W/G24d-1	2	MAG STD 120	120 V Magnetic Standard	36	
1	CFQ13W/G24d-1	1	MAG STD 277	227 V Magnetic Standard	16	
2	CFQ13W/G24d-1	2	MAG STD 277	227 V Magnetic Standard	32	
Compact Fluorescent Quad (13 W, GX23-2 Two Pin Base)						
1	CFQ13W/GX23-2	1	MAG STD	Magnetic Standard	17	4.8" MOL
2	CFQ13W/GX23-2	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (16W GX32d-1 Two Pin Base)						
1	CFQ16W/GX32d-1	1	MAG STD	Magnetic Standard	20	5.5" MOL
2	CFQ16W/GX32d-1	2	MAG STD	Magnetic Standard	40	
Compact Fluorescent Quad (18 W, G24d-2 Two Pin Base - F18DTT Lamp)						
1	CFQ18W/G24d-2	1	MAG STD 120	120 V Magnetic Standard	25	6.8" MOL
2	CFQ18W/G24d-2	2	MAG STD 120	120 V Magnetic Standard	50	
1	CFQ18W/G24d-2	1	MAG STD 277	227 V Magnetic Standard	22	
2	CFQ18W/G24d-2	2	MAG STD 277	227 V Magnetic Standard	44	
Compact Fluorescent Quad (22W, GX32d Two Pin Base)						
1	CFQ22W/GX32d-2	1	MAG STD	Magnetic Standard	27	6.0" MOL
2	CFQ22W/GX32d-2	2	MAG STD	Magnetic Standard	54	
Compact Fluorescent Quad (26 W, G24d-3 Two Pin Base - F26DTT Lamp)						
1	CFQ26W/G24d-3	1	MAG STD 120	120 V Magnetic Standard	37	7.6" MOL
2	CFQ26W/G24d-3	2	MAG STD 120	120 V Magnetic Standard	74	
1	CFQ26W/G24d-3	1	MAG STD 277	227 V Magnetic Standard	33	
2	CFQ26W/G24d-3	2	MAG STD 277	227 V Magnetic Standard	66	
1	CFQ26W/G24d-3	1	ELECT 277V	277 V Electronic	27	
2	CFQ26W/G24d-3	2	ELECT 277V	277 V Electronic	54	

LUMINAIRE POWER

Table B-11

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbrev.	Ballast Description	Watts/ Lumin	Comments
Compact Fluorescent Quad (28W GX32d Two Pin Base)						
1	CFQ28W/GX32d-3	1	MAG STD	Magnetic Standard	34	6.8" MOL
2	CFQ28W/GX32d-3	2	MAG STD	Magnetic Standard	68	
Compact Fluorescent Quad (10 W, G24q-1 Four Pin Base)						
1	CFQ10W/G24q-1	1	MAG STD 120	120 V Magnetic Standard	16	4.6" MOL
2	CFQ10W/G24q-1	2	MAG STD 120	120 V Magnetic Standard	32	
1	CFQ10W/G24q-1	1	MAG STD 277	227 V Magnetic Standard	13	
2	CFQ10W/G24q-1	2	MAG STD 277	227 V Magnetic Standard	26	
Compact Fluorescent Quad (13 W, G24q-1 Four Pin Base)						
1	CFQ13W/G24q-1	1	MAG STD 120	120 V Magnetic Standard	18	6.0" MOL
2	CFQ13W/G24q-1	2	MAG STD 120	120 V Magnetic Standard	36	
1	CFQ13W/G24q-1	1	MAG STD 277	227 V Magnetic Standard	16	
2	CFQ13W/G24q-1	2	MAG STD 277	227 V Magnetic Standard	32	
Compact Fluorescent Quad (13 W, GX7 Four Pin Base)						
1	CFQ13W/GX7	1	MAG STD	Magnetic Standard	17	4.8" MOL
2	CFQ13W/GX7	2	MAG STD	Magnetic Standard	34	
Compact Fluorescent Quad (18 W, G24q-2 Four Pin Base)						
1	CFQ18W/G24q-2	1	MAG STD 120	120 V Magnetic Standard	25	6.8" MOL
2	CFQ18W/G24q-2	2	MAG STD 120	120 V Magnetic Standard	50	
1	CFQ18W/G24q-2	1	MAG STD 277	227 V Magnetic Standard	22	
2	CFQ18W/G24q-2	2	MAG STD 277	227 V Magnetic Standard	44	
Compact Fluorescent Triple (13 W, GX24q-1 Four Pin Base)						
1	CFM 13W/GX24q-1	1	MAG STD	Magnetic Standard	18	4.2" MOL
2	CFM 13W/GX24q-1	2	MAG STD	Magnetic Standard	36	
Compact Fluorescent Triple (18W, GX24q-2 Four Pin Base)						
1	CFM 18W/GX24q-2	1	MAG STD	Magnetic Standard	25	5.0" MOL
2	CFM 18W/GX24q-2	2	MAG STD	Magnetic Standard	50	
Compact Fluorescent Triple (26W, GX24q-3 Four Pin Base)						
1	CFM 26W/GX24q-3	1	MAG STD	Magnetic Standard	37	4.9 to 5.4" MOL
2	CFM 26W/GX24q-3	2	MAG STD	Magnetic Standard	74	

LUMINAIRE POWER Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Twin (18W - F18TT Lamp)						
1	FT18W/2G11	1	MAG EE	Magnetic Energy Efficient	23	
2	FT18W/2G11	1	MAG EE	Magnetic Energy Efficient	46	
3	FT18W/2G11	1.5	MAG EE	Magnetic Energy Efficient	69	Tandem wired
3	FT18W/2G11	2	MAG EE	Magnetic Energy Efficient	69	
4	FT18W/2G11	2	MAG EE	Magnetic Energy Efficient	92	(2) Two-lamp ballasts
1	FT18W/2G11	1	ELECT	Electronic	17	
2	FT18W/2G11	1	ELECT	Electronic	35	
3	FT18W/2G11	1.5	ELECT	Electronic	52	Tandem wired
3	FT18W/2G11	2	ELECT	Electronic	52	
4	FT18W/2G11	2	ELECT	Electronic	70	(2) Two-lamp ballasts
Fluorescent Twin (24-27W- F24TT or F27TT Lamp)						
1	FT24W/2G11	1	MAG EE	Magnetic Energy Efficient	32	
2	FT24W/2G11	1	MAG EE	Magnetic Energy Efficient	66	
3	FT24W/2G11	1.5	MAG EE	Magnetic Energy Efficient	99	Tandem wired
3	FT24W/2G11	2	MAG EE	Magnetic Energy Efficient	98	
4	FT24W/2G11	2	MAG EE	Magnetic Energy Efficient	132	(2) Two-lamp ballasts
1	FT24W/2G11	1	ELECT	Electronic	21	
2	FT24W/2G11	1	ELECT	Electronic	43	
3	FT24W/2G11	1.5	ELECT	Electronic	64	Tandem wired
3	FT24W/2G11	2	ELECT	Electronic	64	
4	FT24W/2G11	2	ELECT	Electronic	86	(2) Two-lamp ballasts
Fluorescent Twin (36-39W - F36TT or F39TT Lamp)						
1	FT36W/2G11	1	MAG EE	Magnetic Energy Efficient	51	
2	FT36W/2G11	1	MAG EE	Magnetic Energy Efficient	66	
3	FT36W/2G11	1.5	MAG EE	Magnetic Energy Efficient	99	Tandem wired
3	FT36W/2G11	2	MAG EE	Magnetic Energy Efficient	117	
4	FT36W/2G11	2	MAG EE	Magnetic Energy Efficient	132	(2) Two-lamp ballasts
1	FT36W/2G11	1	ELECT	Electronic	37	
2	FT36W/2G11	1	ELECT	Electronic	70	
3	FT36W/2G11	1.5	ELECT	Electronic	105	Tandem wired
3	FT36W/2G11	2	ELECT	Electronic	107	
4	FT36W/2G11	2	ELECT	Electronic	140	(2) Two-lamp ballasts

LUMINAIRE LUMIN. Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Twin (40 W - F40TT Lamp)						
1	FT40W/2G11	1	MAG EE	Magnetic Energy Efficient	43	
2	FT40W/2G11	1	MAG EE	Magnetic Energy Efficient	86	
3	FT40W/2G11	1.5	MAG EE	Magnetic Energy Efficient	129	Tandem wired
3	FT40W/2G11	2	MAG EE	Magnetic Energy Efficient	130	
4	FT40W/2G11	2	MAG EE	Magnetic Energy Efficient	172	(2) Two-lamp ballasts
1	FT40W/2G11	1	ELECT	Electronic	36	
2	FT40W/2G11	1	ELECT	Electronic	71	
2	FT40W/2G11	1	ELECT	Electronic	70	
3	FT40W/2G11	1	ELECT	Electronic	98	
3	FT40W/2G11	1.5	ELECT	Electronic	106	Tandem wired
3	FT40W/2G11	2	ELECT	Electronic	107	
4	FT40W/2G11	2	ELECT	Electronic	142	(2) Two-lamp ballasts
2	FT40W/2G11	1	ELECT RO	Elec. Reduce Output (75%)	59	
3	FT40W/2G11	1.5	ELECT DIM	Electronic Dimming (to 1%)	105	Tandem wired
4	FT40W/2G11	2	ELECT DIM	Electronic Dimming (to 1%)	140	(2) two-lamp ballasts
Fluorescent Twin (50 W - F50TT Lamp)						
1	FT50W/2G11	1	ELECT	Electronic	54	
2	FT50W/2G11	1	ELECT	Electronic	106	
3	FT50W/2G11	1	ELECT	Electronic	98	
3	FT50W/2G11	1.5	ELECT	Electronic	159	Tandem wired
3	FT50W/2G11	2	ELECT	Electronic	160	
4	FT50W/2G11	2	ELECT	Electronic	212	(2) Two-lamp ballasts
Fluorescent Twin (55 W - F55TT Lamp)						
1	FT55W/2G11	1	ELECT	Electronic	62	
2 ft. Fluorescent U-Tube Octic (32W - FBO31T8 Lamp)						
1	FB31T8	0.5	MAG EE	Magnetic Energy Efficient	35	Tandem wired
1	FB31T8	1	MAG EE	Magnetic Energy Efficient	36	
2	FB31T8	1	MAG EE	Magnetic Energy Efficient	69	
3	FB31T8	1.5	MAG EE	Magnetic Energy Efficient	104	Tandem wired
3	FB31T8	2	MAG EE	Magnetic Energy Efficient	105	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbrev.	Description	Lumin	Comments
1	FB31T8	0.5	ELECT	Electronic	31	Tandem wired
1	FB31T8	1	ELECT	Electronic	39	
2	FB31T8	1	ELECT	Electronic	62	
3	FB31T8	1	ELECT	Electronic	92	
3	FB31T8	1.5	ELECT	Electronic	93	Tandem wired
3	FB31T8	2	ELECT	Electronic	101	
2	FB31T8	1	ELECT IS	Electronic Instant Start	61	
3	FB31T8	1	ELECT IS	Electronic Instant Start	88	
2 ft. Fluorescent U-Tube Energy-Saving (34W)						
1	FB40T12/ES	0.5	MAG EE	Magnetic Energy Efficient	36	Tandem wired
1	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	43	
2	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	72	
3	FB40T12/ES	1	MAG EE	Magnetic Energy Efficient	105	
3	FB40T12/ES	1.5	MAG EE	Magnetic Energy Efficient	108	Tandem wired
3	FB40T12/ES	2	MAG EE	Magnetic Energy Efficient	115	
1	FB40T12/ES	0.5	ELECT	Electronic	30	Tandem wired
1	FB40T12/ES	1	ELECT	Electronic	31	
2	FB40T12/ES	1	ELECT	Electronic	59	
3	FB40T12/ES	1	ELECT	Electronic	90	
3	FB40T12/ES	1.5	ELECT	Electronic	88	Tandem wired
3	FB40T12/ES	2	ELECT	Electronic	90	
2 ft. Fluorescent U-Tube Standard (40W - FB40T12 Lamp)						
1	FB40T12	0.5	MAG EE	Magnetic Energy Efficient	43	Tandem wired
1	FB40T12	1	MAG EE	Magnetic Energy Efficient	48	
2	FB40T12	1	MAG EE	Magnetic Energy Efficient	86	
3	FB40T12	1	MAG EE	Magnetic Energy Efficient	127	
3	FB40T12	1.5	MAG EE	Magnetic Energy Efficient	129	Tandem wired
3	FB40T12	2	MAG EE	Magnetic Energy Efficient	134	
1	FB40T12	0.5	ELECT	Electronic	35	Tandem wired
1	FB40T12	1	ELECT	Electronic	36	
2	FB40T12	1	ELECT	Electronic	67	
3	FB40T12	1	ELECT	Electronic	100	
3	FB40T12	1.5	ELECT	Electronic	101	Tandem wired
3	FB40T12	2	ELECT	Electronic	103	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Fluorescent Preheat T5 (4W)						
1	F4T5	1	MAG STD	Magnetic Standard	8	6" MOL
Fluorescent Preheat T5 (6W)						
1	F6T5	1	MAG STD	Magnetic Standard	10	9" MOL
Fluorescent Preheat T5 (8W)						
1	F8T5	1	MAG STD	Magnetic Standard	12	12" MOL
Fluorescent Preheat T8 (15W)						
1	F15T8	1	MAG STD	Magnetic Standard	19	18" MOL
Fluorescent Preheat T12 (15W)						
1	F15T12	1	MAG STD	Magnetic Standard	19	18" MOL
Fluorescent Preheat T12 (20W)						
1	F20T12	1	MAG STD	Magnetic Standard	25	24" MOL
2	F20T12	1	MAG STD	Magnetic Standard	50	24" MOL
Fluorescent Preheat T8 (30W)						
1	F30T8	1	MAG STD	Magnetic Standard	46	30" MOL
2	F30T8	1	MAG STD	Magnetic Standard	79	30" MOL
Fluorescent Preheat T12 (30W)						
1	F30T12	1	MAG STD	Magnetic Standard	46	30" MOL
2	F30T12	1	MAG STD	Magnetic Standard	79	30" MOL
2	F30T12	1	MAG EE	Magnetic Energy Efficient	74	30" MOL
1	F30T12	1	ELECT	Electronic	31	30" MOL
2	F30T12	2	ELECT	Electronic	63	30" MOL
2 foot Fluorescent Rapid Start T8 (17W)						
1	F17T8	1	MAG EE	Magnetic Energy Efficient	24	
2	F17T8	1	MAG EE	Magnetic Energy Efficient	45	
1	F17T8	1	ELECT	Electronic	22	
2	F17T8	1	ELECT	Electronic	33	
3	F17T8	1	ELECT	Electronic	53	
3	F17T8	2	ELECT	Electronic	55	
4	F17T8	1	ELECT	Electronic	63	
4	F17T8	2	ELECT	Electronic	66	(2) two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbrev.	Ballast Description	Watts/ Lumin	Comments
3 foot Fluorescent Rapid Start T8 (25W)						
1	F25T8	1	MAG EE	Magnetic Energy Efficient	33	
2	F25T8	1	MAG EE	Magnetic Energy Efficient	65	
1	F25T8	1	ELECT	Electronic	27	
2	F25T8	1	ELECT	Electronic	48	
3	F25T8	1	ELECT	Electronic	68	
3	F25T8	2	ELECT	Electronic	75	
4	F25T8	1	ELECT	Electronic	89	
4	F25T8	2	ELECT	Electronic	96	(2) two-lamp ballasts
4 foot Fluorescent Rapid Start Octic (32W)						
1	F32T8	0.5	MAG EE	Magnetic Energy Efficient	35	Tandem wired
1	F32T8	1	MAG EE	Magnetic Energy Efficient	39	
2	F32T8	1	MAG EE	Magnetic Energy Efficient	70	
3	F32T8	1.5	MAG EE	Magnetic Energy Efficient	105	Tandem wired
3	F32T8	2	MAG EE	Magnetic Energy Efficient	109	
4	F32T8	2	MAG EE	Magnetic Energy Efficient	140	(2) two-lamp ballasts
1	F32T8	0.5	ELECT	Electronic	31	Tandem wired
1	F32T8	1	ELECT	Electronic	32	
2	F32T8	1	ELECT	Electronic	62	
3	F32T8	1	ELECT	Electronic	93	
3	F32T8	1.5	ELECT	Electronic	93	Tandem wired
3	F32T8	2	ELECT	Electronic	94	
4	F32T8	1	ELECT	Electronic	114	
4	F32T8	2	ELECT	Electronic	124	(2) two-lamp ballasts
2	F32T8	1	ELECT IS	Electronic Instant Start	63	
3	F32T8	1	ELECT IS	Electronic Instant Start	96	
3	F32T8	1.5	ELECT IS	Electronic Instant Start	95	Tandem wired
4	F32T8	1	ELECT IS	Electronic Instant Start	124	
4	F32T8	2	ELECT IS	Electronic Instant Start	126	(2) two-lamp ballasts

LUMINAIRE POWER Table B-11

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbrev.	Ballast Description	Watts/ Lumin	Comments
4 foot Fluorescent Rapid Start Octic (32W) (cont.)						
2	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	51	
3	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	76	
3	F32T8	1.5	ELECT RO	Electronic Reduce Output (75%)	77	Tandem wired
4	F32T8	1	ELECT RO	Electronic Reduce Output (75%)	100	
4	F32T8	2	ELECT RO	Electronic Reduce Output (75%)	102	(2) two-lamp ballasts
2	F32T8	1	ELECT TL	Electronic Two Level (50 & 100%)	65	
3	F32T8	1.5	ELECT TL	Electronic Two Level (50 & 100%)	98	Tandem wired
4	F32T8	2	ELECT TL	Electronic Two Level (50 & 100%)	130	(2) two-lamp ballasts
2	F32T8	1	ELECT AO	Electronic Adjustable Output (to 15%)	73	
3	F32T8	1.5	ELECT AO	Electronic Adjustable Output (to 15%)	110	Tandem wired
4	F32T8	2	ELECT AO	Electronic Adjustable Output (to 15%)	146	(2) two-lamp ballasts
2	F32T8	1	ELECT DIM	Electronic Dimming (to 1%)	75	
3	F32T8	1.5	ELECT DIM	Electronic Dimming (to 1%)	113	Tandem wired
4	F32T8	2	ELECT DIM	Electronic Dimming (to 1%)	150	(2) two-lamp ballasts
5 foot Fluorescent Rapid Start (40W)						
1	F40T8	1	MAG EE	Magnetic Energy Efficient	50	
2	F40T8	1	MAG EE	Magnetic Energy Efficient	92	
1	F40T8	1	ELECT	Electronic	46	
2	F40T8	1	ELECT	Electronic	79	
3	F40T8	2	ELECT	Electronic	109	
3 foot Fluorescent Rapid Start Energy-Saving (25W)						
1	F30T12/ES	1	MAG STD	Magnetic Standard	42	
2	F30T12/ES	1	MAG STD	Magnetic Standard	74	
3	F30T12/ES	1.5	MAG STD	Magnetic Standard	111	Tandem wired
3	F30T12/ES	2	MAG STD	Magnetic Standard	116	
2	F30T12/ES	1	MAG EE	Magnetic Energy Efficient	66	
1	F30T12/ES	1	ELECT	Electronic	26	
2	F30T12/ES	1	ELECT	Electronic	53	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbrev.	Description	Lumin	Comments
3 foot Fluorescent Rapid Start Standard (30W)						
1	F30T12	1	MAG STD	Magnetic Standard	46	
2	F30T12	1	MAG STD	Magnetic Standard	79	
3	F30T12	1.5	MAG STD	Magnetic Standard	118	Tandem wired
3	F30T12	2	MAG STD	Magnetic Standard	125	
4 foot Fluorescent Rapid Start Energy-Saving Plus (32W)						
1	F40T12/ES Plus	0.5	MAG EE	Magnetic Energy Efficient	34	Tandem wired
1	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	41	
2	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	68	
3	F40T12/ES Plus	1	MAG EE	Magnetic Energy Efficient	99	
3	F40T12/ES Plus	1.5	MAG EE	Magnetic Energy Efficient	102	Tandem wired
3	F40T12/ES Plus	2	MAG EE	Magnetic Energy Efficient	109	
4	F40T12/ES Plus	2	MAG EE	Magnetic Energy Efficient	136	(2) Two-lamp ballasts
4 foot Fluorescent Rapid Start Energy-Saving (34W)						
1	F40T12/ES	0.5	MAG STD**	Magnetic Standard	42	Tandem wired
1	F40T12/ES	1	MAG STD**	Magnetic Standard	48	
2	F40T12/ES	1	MAG STD**	Magnetic Standard	82	
3	F40T12/ES	1.5	MAG STD**	Magnetic Standard	122	Tandem wired
3	F40T12/ES	2	MAG STD**	Magnetic Standard	130	
4	F40T12/ES	2	MAG STD**	Magnetic Standard	164	(2) Two-lamp ballasts
1	F40T12/ES	0.5	MAG EE	Magnetic Energy Efficient	36	Tandem wired
1	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	43	
2	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	72	
3	F40T12/ES	1	MAG EE	Magnetic Energy Efficient	105	
3	F40T12/ES	1.5	MAG EE	Magnetic Energy Efficient	108	Tandem wired
3	F40T12/ES	2	MAG EE	Magnetic Energy Efficient	112	
4	F40T12/ES	2	MAG EE	Magnetic Energy Efficient	144	(2) Two-lamp ballasts
2	F40T12/ES	1	MAG HC	Magnetic Heater Cutout	58	
3	F40T12/ES	1.5	MAG HC	Magnetic Heater Cutout	87	Tandem wired
4	F40T12/ES	2	MAG HC	Magnetic Heater Cutout	116	(2) Two-lamp ballasts
2	F40T12/ES	1	MAG HC FO	Mag. Heater Cutout Full Light	66	
3	F40T12/ES	1.5	MAG HC FO	Mag. Heater Cutout Full Light	99	Tandem wired
4	F40T12/ES	2	MAG HC FO	Mag. Heater Cutout Full Light	132	(2) Two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp No.	Lamp Designation	Ballast No.	Ballast Abbrev.	Ballast Description	Watts/ Lumin	Comments
4 foot Fluorescent Rapid Start Energy-Saving (34W) (cont.)						
1	F40T12/ES	0.5	ELECT	Electronic	30	Tandem wired
1	F40T12/ES	1	ELECT	Electronic	31	
2	F40T12/ES	1	ELECT	Electronic	62	
3	F40T12/ES	1	ELECT	Electronic	90	
3	F40T12/ES	1.5	ELECT	Electronic	93	Tandem wired
3	F40T12/ES	2	ELECT	Electronic	93	
4	F40T12/ES	1	ELECT	Electronic	121	
4	F40T12/ES	2	ELECT	Electronic	124	(2) Two-lamp ballasts
2	F40T12/ES	1	ELECT AO	Elec. Adjustable Output (to 15%)	60	
3	F40T12/ES	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	90	Tandem wired
4	F40T12/ES	2	ELECT AO	Elec. Adjustable Output (to 15%)	120	(2) Two-lamp ballasts
4 foot Fluorescent Rapid Start Standard (40W)						
1	F40T12	0.5	MAG STD**	Magnetic Standard	26	Tandem wired
1	F40T12	1	MAG STD**	Magnetic Standard	52	
2	F40T12	1	MAG STD**	Magnetic Standard	96	
3	F40T12	1.5	MAG STD**	Magnetic Standard	144	Tandem wired
3	F40T12	2	MAG STD**	Magnetic Standard	148	
4	F40T12	2	MAG STD**	Magnetic Standard	192	(2) Two-lamp ballasts
1	F40T12	0.5	MAG EE	Magnetic Energy Efficient	44	Tandem wired
1	F40T12	1	MAG EE	Magnetic Energy Efficient	46	
2	F40T12	1	MAG EE	Magnetic Energy Efficient	88	
3	F40T12	1	MAG EE	Magnetic Energy Efficient	127	
3	F40T12	1.5	MAG EE	Magnetic Energy Efficient	132	Tandem wired
3	F40T12	2	MAG EE	Magnetic Energy Efficient	134	
4	F40T12	2	MAG EE	Magnetic Energy Efficient	176	(2) Two-lamp ballasts
2	F40T12	1	MAG HC	Magnetic Heater Cutout	71	
3	F40T12	1.5	MAG HC	Magnetic Heater Cutout	107	Tandem wired
4	F40T12	2	MAG HC	Magnetic Heater Cutout	142	(2) Two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbrev.	Description	Lumin	Comments
4 foot Fluorescent Rapid Start Standard (40W) (cont.)						
2	F40T12	1	MAG HC FO	Magnetic Heater Cutout Full Light	80	
3	F40T12	1.5	MAG HC FO	Magnetic Heater Cutout Full Light	120	Tandem wired
4	F40T12	2	MAG HC FO	Magnetic Heater Cutout Full Light	160	(2) Two-lamp ballasts
1	F40T12	0.5	ELECT	Electronic	36	Tandem wired
1	F40T12	1	ELECT	Electronic	37	
2	F40T12	1	ELECT	Electronic	72	
3	F40T12	1	ELECT	Electronic	107	
3	F40T12	1.5	ELECT	Electronic	108	Tandem wired
3	F40T12	2	ELECT	Electronic	109	
4	F40T12	1	ELECT	Electronic	135	
4	F40T12	2	ELECT	Electronic	144	(2) Two-lamp ballasts
2	F40T12	1	ELECT RO	Electronic Reduce Output (75%)	61	
3	F40T12	1	ELECT RO	Electronic Reduce Output (75%)	90	
3	F40T12	1.5	ELECT RO	Electronic Reduce Output (75%)	92	Tandem wired
4	F40T12	2	ELECT RO	Electronic Reduce Output (75%)	122	(2) Two-lamp ballasts
2	F40T12	1	ELECT TL	Elec. Two Level (50 & 100%)	69	
3	F40T12	1.5	ELECT TL	Elec. Two Level (50 & 100%)	104	Tandem wired
4	F40T12	2	ELECT TL	Elec. Two Level (50 & 100%)	138	(2) Two-lamp ballasts
2	F40T12	1	ELECT AO	Elec. Adjustable Output (to 15%)	73	
3	F40T12	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	110	Tandem wired
4	F40T12	2	ELECT AO	Elec. Adjustable Output (to 15%)	146	(2) Two-lamp ballasts
2	F40T12	1	ELECT DIM	Electronic Dimming (to 1%)	83	
3	F40T12	1.5	ELECT DIM	Electronic Dimming (to 1%)	125	Tandem wired
4	F40T12	2	ELECT DIM	Electronic Dimming (to 1%)	166	(2) Two-lamp ballasts

LUMINAIRE POWER Table B-11

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbrev.	Description	Lumin	Comments
4 foot Fluorescent Rapid Start Extended Output (42W)						
2	F40T10/EO	1	MAG EE	Magnetic Energy Efficient	92	
3	F40T10/EO	1.5	MAG EE	Magnetic Energy Efficient	138	Tandem wired
4	F40T10/EO	2	MAG EE	Magnetic Energy Efficient	184	(2) Two-lamp ballasts
2	F40T10/EO	1	MAG HC	Magnetic Heater Cutout	74	
3	F40T10/EO	1.5	MAG HC	Magnetic Heater Cutout	111	Tandem wired
4	F40T10/EO	2	MAG HC	Magnetic Heater Cutout	148	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT	Electronic	74	
3	F40T10/EO	1.5	ELECT	Electronic	111	Tandem wired
4	F40T10/EO	2	ELECT	Electronic	148	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT RO	Electronic Reduce Output (75%)	63	
3	F40T10/EO	1.5	ELECT RO	Electronic Reduce Output (75%)	95	Tandem wired
4	F40T10/EO	2	ELECT RO	Electronic Reduce Output (75%)	126	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT TL	Elec. Two Level (50 & 100%)	72	
3	F40T10/EO	1.5	ELECT TL	Elec. Two Level (50 & 100%)	108	Tandem wired
4	F40T10/EO	2	ELECT TL	Elec. Two Level (50 & 100%)	144	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT AO	Elec. Adjustable Output (to 15%)	73	
3	F40T10/EO	1.5	ELECT AO	Elec. Adjustable Output (to 15%)	110	Tandem wired
4	F40T10/EO	2	ELECT AO	Elec. Adjustable Output (to 15%)	146	(2) Two-lamp ballasts
2	F40T10/EO	1	ELECT DIM	Electronic Dimming (to 1%)	85	
3	F40T10/EO	1.5	ELECT DIM	Electronic Dimming (to 1%)	128	Tandem wired
4	F40T10/EO	2	ELECT DIM	Electronic Dimming (to 1%)	170	(2) Two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
8 foot Fluorescent Rapid Start High Output Energy-Saving (86W)						
2	F96T8/HO	1	ELECT	Electronic	160	
8 foot Fluorescent Rapid Start High Output Energy-Saving (95W)						
1	F96T12/HO/ES	1	MAG STD	Magnetic Standard	125	
2	F96T12/HO/ES	1	MAG STD**	Magnetic Standard	227	
2	F96T12/HO/ES	1	MAG EE	Magnetic Energy Efficient	208	
4	F96T12/HO/ES	2	MAG EE	Magnetic Energy Efficient	416	(2) Two-lamp ballasts
2	F96T12/HO/ES	1	ELECT	Electronic	160	
4	F96T12/HO/ES	2	ELECT	Electronic	320	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start High Output (110W)						
1	F96T12/HO	1	MAG STD	Magnetic Standard	140	
2	F96T12/HO	1	MAG STD**	Magnetic Standard	252	
2	F96T12/HO	1	MAG EE	Magnetic Energy Efficient	237	
4	F96T12/HO	2	MAG EE	Magnetic Energy Efficient	474	(2) Two-lamp ballasts
2	F96T12/HO	1	ELECT	Electronic	190	
4	F96T12/HO	2	ELECT	Electronic	380	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start Very High Output Energy-Saving (195W)						
1	F96T12/VHO/ES	1	MAG STD	Magnetic Standard	200	
2	F96T12/VHO/ES	1	MAG STD	Magnetic Standard	325	
4	F96T12/VHO/ES	2	MAG STD	Magnetic Standard	650	(2) Two-lamp ballasts
8 foot Fluorescent Rapid Start Very High Output (215W)						
1	F96T12/VHO	1	MAG STD	Magnetic Standard	230	
2	F96T12/VHO	1	MAG STD	Magnetic Standard	440	
4	F96T12/VHO	2	MAG STD	Magnetic Standard	880	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/	
No.	Designation	No.	Abbrev.	Description	Lumin	Comments
4 foot Fluorescent Slimline Energy-Saving T12 (32W)						
1	F48T12/ES	1	MAG STD	Magnetic Standard	51	
2	F48T12/ES	1	MAG STD	Magnetic Standard	82	
4 foot Fluorescent Slimline Standard T12 (39W)						
1	F48T12	1	MAG STD	Magnetic Standard	59	
2	F48T12	1	MAG STD	Magnetic Standard	98	
8 foot Fluorescent Instant Start T8 (Slimline with Rare Earth Phosphors)						
1	F96T8	1	ELECT	Electronic	71	
2	F96T8	1	ELECT	Electronic	115	
8 foot Fluorescent Slimline Energy-Saving (60W)						
1	F96T12/ES	1	MAG STD	Magnetic Standard	83	
2	F96T12/ES	1	MAG STD**	Magnetic Standard	138	
2	F96T12/ES	1	MAG EE	Magnetic Energy Efficient	123	
4	F96T12/ES	2	MAG EE	Magnetic Energy Efficient	246	(2) Two-lamp ballasts
2	F96T12/ES	1	ELECT	Electronic	105	
4	F96T12/ES	2	ELECT	Electronic	210	(2) Two-lamp ballasts
8 foot Fluorescent Slimline Standard (75W)						
1	F96T12	1	MAG STD	Magnetic Standard	100	
2	F96T12	1	MAG STD**	Magnetic Standard	173	
2	F96T12	1	MAG EE	Magnetic Energy Efficient	158	
4	F96T12	2	MAG EE	Magnetic Energy Efficient	316	(2) Two-lamp ballasts
2	F96T12	1	ELECT	Electronic	130	
4	F96T12	2	ELECT	Electronic	260	(2) Two-lamp ballasts
2	F96T12	1	ELECT IS	Electronic Instant Start	130	
3	F96T12	1.5	ELECT IS	Electronic Instant Start	195	Tandem wired
4	F96T12	2	ELECT IS	Electronic Instant Start	260	(2) Two-lamp ballasts

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
Mercury Vapor						
1	MV40	1	MAG STD	Magnetic Standard	51	
1	MV50	1	MAG STD	Magnetic Standard	63	
1	MV75	1	MAG STD	Magnetic Standard	88	
1	MV100	1	MAG STD	Magnetic Standard	119	
1	MV175	1	MAG STD	Magnetic Standard	197	
1	MV250	1	MAG STD	Magnetic Standard	285	
1	MV400	1	MAG STD	Magnetic Standard	450	
1	MV1000	1	MAG STD	Magnetic Standard	1080	
Metal Halide						
1	MH32	1	MAG STD	Magnetic Standard	42	
1	MH70	1	MAG STD	Magnetic Standard	95	
1	MH100	1	MAG STD	Magnetic Standard	142	
1	MH175	1	MAG STD	Magnetic Standard	210	
1	MH250	1	MAG STD	Magnetic Standard	295	
1	MH400	1	MAG STD	Magnetic Standard	461	
1	MH1000	1	MAG STD	Magnetic Standard	1080	
High Pressure Sodium						
1	HPS35	1	MAG STD	Magnetic Standard	44	
1	HPS50	1	MAG STD	Magnetic Standard	61	
1	HPS70	1	MAG STD	Magnetic Standard	93	
1	HPS100	1	MAG STD	Magnetic Standard	116	
1	HPS150	1	MAG STD	Magnetic Standard	173	
1	HPS200	1	MAG STD	Magnetic Standard	240	
1	HPS250	1	MAG STD	Magnetic Standard	302	
1	HPS400	1	MAG STD	Magnetic Standard	469	
1	HPS1000	1	MAG STD	Magnetic Standard	1090	
Low Pressure Sodium						
1	LPS18	1	MAG STD	Magnetic Standard	30	
1	LPS35	1	MAG STD	Magnetic Standard	60	
1	LPS55	1	MAG STD	Magnetic Standard	80	
1	LPS90	1	MAG STD	Magnetic Standard	125	
1	LPS135	1	MAG STD	Magnetic Standard	178	
1	LPS180	1	MAG STD	Magnetic Standard	220	

LUMINAIRE POWER

Table B-11

Lamp		Ballast			Watts/ Lumin	Comments
No.	Designation	No.	Abbrev.	Description		
12 Volt Tungsten Halogen, MR 16 & Electronic Transformer						
1	Q20MR16(12V)	1	ELECT	Electronic	23	
1	Q35MR16(12V)	1	ELECT	Electronic	39	
1	Q50MR16(12V)	1	ELECT	Electronic	55	
1	Q70MR16(12V)	1	ELECT	Electronic	78	

*** US Energy Policy Act of 1992 affect on lamps**

Beginning in April 1994, many common wattage lamp types can no longer be
Lamp Types affected include the following fluorescent lamps:
manufactured or imported into the U.S. Federal Energy Legislation has decreed that these lamp types must be eliminated to reduce energy consumption.

Fluorescent Lamps	F40U/3 Cool White	F96T12/ W
F40 CW	F40U/3 Warm White	F96T12/ WW
F40 D	F40U/6 Cool White	F96T12/ WWX
F40 D/WM	F40U/6 Warm White Deluxe	F96T12/ WWX/WM
F40 W	F40U/6 Warm White	F96T12/ HO/D
F40 WW	F96T1 2/ CW	F96T12/ HO/CW
F40 WWX	F96T1 2/ D	F96T12/ HO/W
F40 WWX/WM	F96T1 2/ D/WM	F96T12/ HO/WW

Incandescent PAR Lamps		Inc. Reflector Lamps
75PAR38	150PAR38	75R40 200R40
75/65PAR38	150/120PAR38	75R30
100/80PAR38		150R40
100 PAR38		100R40

**** US National Appliance Energy Conservation Act of 1988 affect on ballasts**

In 1991 using the following Standard Magnetic ballasts was not permitted in the US.

- -Single and two-lamp ballasts for 4' T12 Rapid Start Lamps, 120V & 277V 60Hz
- -Two-lamp ballasts for 8' T-12 Slimline lamps
- -Two-lamp ballasts for 8' T12 high-output rapid start lamps

C: California Design Location Data

The data contained in the following tables was obtained through a joint effort by the Southern California Chapter and the Golden Gate Chapter of ASHRAE. It is reprinted here with the written permission of Southern California Chapter ASHRAE, Inc.

A full listing of design location data for California is contained in the ASHRAE publication *SPCDX, Climate Data for Region X, Arizona, California, Hawaii, and Nevada* (May 1982). The publication may be ordered from:

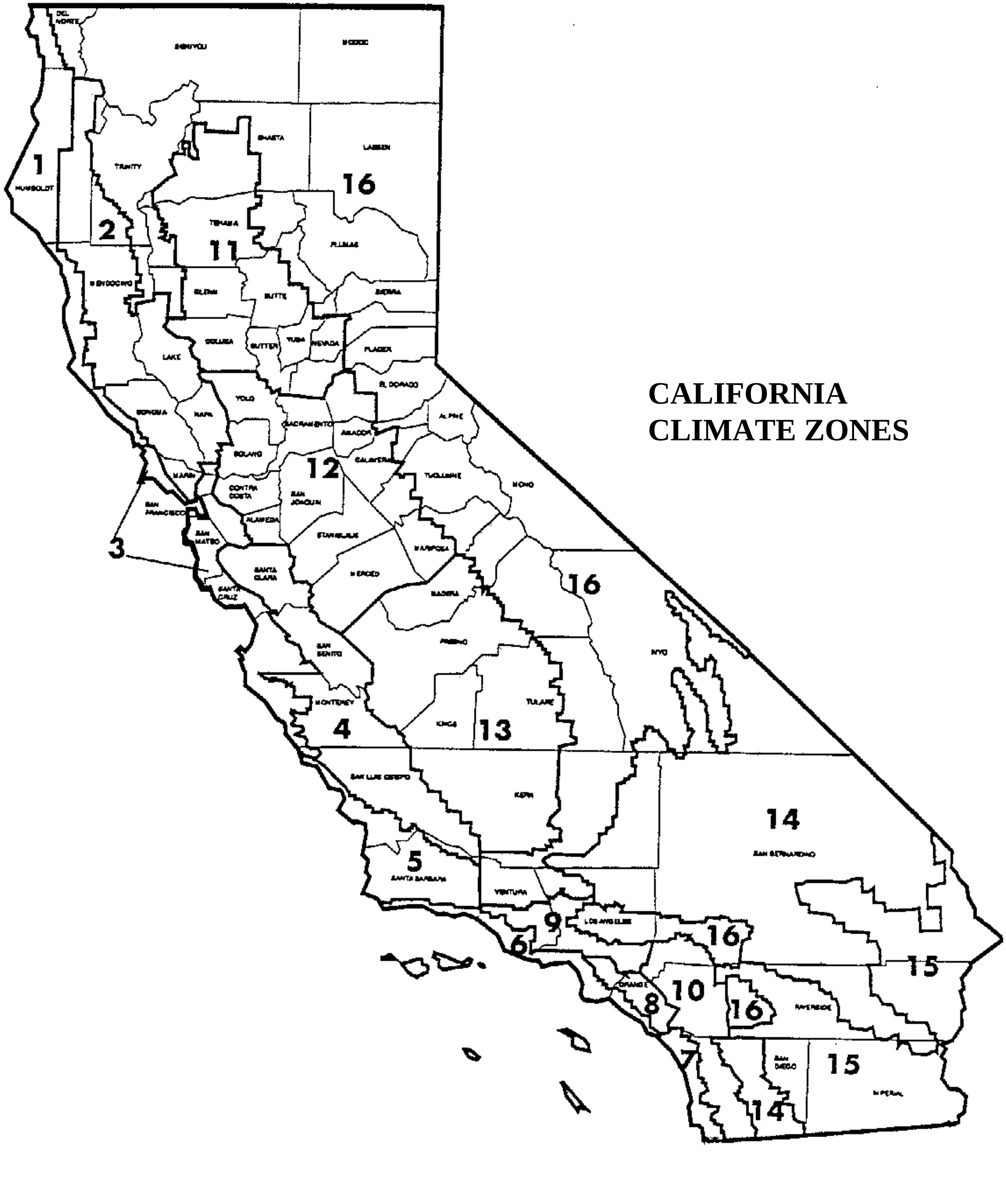
Order Desk
Building News
10801 National Blvd.
Los Angeles, CA 90064
(800) 873-6397 or (310) 474-7771

Cost: $29.95 + tax + shipping and handling

KEY TO ABBREVIATIONS:

AFB	Air Force Base
AFS	Air Force Station
AP	Airport
CO	City/County Office
FD	Fire Department
FS	Fire Station
MCB	Marine Corps Base
NAS	Naval Air Station
NM	National Monument
PH	Power House
RS	Ranger Station

CALIFORNIA CLIMATE ZONES



City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer							Winter Minimum	HDD
						.1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range		
Adin RS	Modoc	16	41.20	120 57	4195	96	61	92	60	88	59	43	-7	
Alameda NAS	Alameda	3	37.79	122 19	15	88	65	82	64	76	62	21	35	2507
Alamo	Contra Costa	12	37.90	122 55	410	102	69	97	68	92	66	30	23	
Albany	Alameda	3	37.90	122 15	40	88	65	83	64	77	62	16	30	
Alderpoint	Humboldt	2	40.20	123 37	460	100	69	95	67	90	65	39	21	3424
Alhambra	Los Angeles	9	34		483	100	71	96	70	90	68	25	30	
Almaden AFS	Santa Clara	3	37.20	121 54	3470	95	62	90	60	85	59	20	20	4468
Alondra Park	Los Angeles	6	33.90		50	91	69	86	68	81	66	17	35	
Alpine	San Diego	10	32.79	116 46	1735	99	69	95	68	91	67	35	27	
Altadena	Los Angeles	9	34.20		1200	99	68	94	67	88	66	31	32	1920
Alturas RS	Modoc	16	41.5	120 33	4400	99	62	96	61	91	59	43	-10	6895
Alum Rock	Santa Clara	4	37.40	121 50	70	95	68	90	66	84	64	22	28	
Anaheim	Orange	8	33.79		158	99	69	92	68	85	67	26	32	
Anderson	Shasta	11	40.5	122 15	430	107	71	103	70	97	68	30	26	
Angwin	Napa	2	38.59	122 25	1815	98	66	93	64	88	62	33	25	
Antioch	Contra Costa	12	38	121 46	60	102	70	97	68	91	66	34	22	2627
Apple Valley	San Bernardino	14	34.5		2935	105	66	101	65	97	64	38	14	
Aptos	Santa Cruz	3	37		500	94	67	88	66	83	63	30	27	
Arcadia	Los Angeles	9	34.20		475	100	69	96	68	91	67	30	31	
Arcata	Humboldt	1	41	124 06	218	75	61	69	59	65	58	11	28	5029
Arden	Sacramento	12	38.5		80	104	70	100	69	94	67	35	28	
Arroyo Grande	San Luis	5	35.09		105	92	66	86	64	79	62	18	28	
Artesia	Los Angeles	8	33.79		50	99	71	91	70	85	68	23	33	
Arvin	Kern	13	35.20		445	106	71	102	69	98	68	30	26	
Ash Mtn	Tulare	13	36.5	118 50	1708	105	69	101	68	97	66	30	25	2703
Atascadero	San Luis	4	35.5	120 42	837	94	66	89	67	84	65	42	25	
Atherton	San Mateo	3	37.5	122 14	50	90	66	84	64	78	62	27	23	
Atwater	Merced	12	37.29		150	102	72	99	70	94	67	38	24	
Auberry	Fresno	13	37.09	119 30	2140	102	69	98	67	95	64	36	21	3313
Auburn	Placer	11	38.90	121 04	1292	103	69	100	67	95	66	33	25	3089
Avalon	Los Angeles	6	33.40	118 19	25	83	64	75	62	69	60	11	37	2204
Azusa	Los Angeles	9	34.09	118 09	605	101	70	97	69	91	68	36	31	
Baker	San Bernardino	14	35.29	116 06	940	115	73	112	72	108	70	29	23	
Bakersfield AP	Kern	13	35.40	119 03	475	106	71	102	70	98	68	34	26	2185
Balch PH	San Bernardino	14	36.90		1720	100	67	97	66	93	64	26	26	
Baldwin Park	Los Angeles	9	34		394	100	69	96	69	90	68	32	31	
Banning	Riverside	15	33.90	116 53	2349	104	69	100	68	96	67	34	20	
Barrett Dam	San Diego	10	32.70	116 40	1623	103	69	97	68	92	67	35	22	2656
Barstow	San Bernardino	14	34.90	117 02	2162	107	69	104	69	100	67	35	16	2580
Beale AFB	Yuba	11	39.09	121 26	113	105	71	102	70	97	68	34	25	2835
Beaumont	Riverside	10	33.90	116 58	2605	103	68	99	67	95	66	38	22	2628
Bell	Los Angeles	8	33.90		143	97	70	91	69	85	67	22	33	
Bell Gardens	Los Angeles	8	33.90		160	97	70	91	69	78	62	24	29	
Bellflower	Los Angeles	8	33.79		73	98	70	91	69	85	67	21	32	
Belmont	San Mateo	3	37.5		33	90	66	84	64	78	62	24	29	
Ben Lomond	Santa Cruz	3	37.09	122 06	450	92	67	85	66	79	63	30	25	
Benicia	Solano	12	38.09	122 06	55	99	69	93	67	87	65	30	28	
Berkeley	Alameda	3	37.90	122 15	345	90	64	83	63	76	61	16	33	2950
Berryessa Lake	Napa	2	38.59	122 03	480	102	70	98	69	92	67	35	26	

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer							Winter Minimum	HDD
						.1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range		
Beverly Hills	Los Angeles	9	34.09	118 10	268	94	69	88	68	83	66	20	39	
Big Bar RS	Trinity	16	40.79	121 48	1260	102	68	98	67	93	65	46	19	
Big Bear Lake	San Bernardino	16	34.20	116 53	6745	87	59	83	58	79	56	32	-3	6850
Bishop AP	Inyo	16	37.40	118 22	4108	103	61	100	60	97	58	40	5	4313
Blackwells Corner	Kern	13	35.59	119 54	644	99	68	94	66	89	65	31	23	
Bloomington	San Bernardino	10	34		980	106	71	102	70	98	69	34	30	
Blue Canyon AP	Placer	16	39.29	120 42	5280	88	60	85	59	81	57	20	13	5704
Blythe AP	Riverside	15	33.59	114 43	395	115	74	112	73	108	71	27	28	1219
Blythe CO	Riverside	15	33.59	114 36	268	115	74	112	73	108	71	27	24	1312
Boca	Nevada	16	39.40	120 06	5575	92	58	89	57	84	55	46	-18	8340
Bodie	Mono	16	38.20	119 01	8370	83	50	80	49	76	48	42	-21	
Bonita	Madera	13	32.70	117 02	105	91	69	82	67	78	64	20	28	1864
Boron AFS	Kern	14	35.09	117 35	3015	106	70	103	69	98	68	35	18	3000
Borrego Desert PK	San Diego	15	33.20	116 24	805	112	76	107	74	101	72	36	25	
Bowman Dam	Placer	11	39.40	120 39	5347	89	59	86	57	82	55	26	9	5964
Brannan Island	Sacramento	12	38.09	121 42	30	100	69	95	68	89	67	10	24	
Brawley 2 SW	Imperial	15	33	115 33	-100	113	74	110	73	105	73	32	25	1204
Brea Dam	Orange	8	33.90		275	100	69	94	68	86	66	29	30	
Bridgeport	Mono	16	38.20	119 13	6470	89	56	86	54	82	53	41	-20	
Broderick-Bryte	Yolo	12	38.59	121 30	20	104	71	100	69	94	67	36	25	
Brooks Ranch	Yolo	12	38.79	122 09	294	104	71	99	70	93	68	35	19	2968
Buena Park	Orange	8	33.90		75	98	69	92	68	85	67	25	31	
Burbank AP	Los Angeles	9	34.20	118 21	699	101	70	96	68	90	67	28	29	1701
Burbank Vly Pump	Los Angeles	9	34.20	118 21	655	101	69	96	68	90	66	28	29	1678
Burlingame	San Mateo	3	37.59	122 21	10	88	67	82	64	76	63	20	30	
Burney	Shasta	16	40.90	121 40	3127	95	64	92	63	88	61	42	0	6404
Butler Valley			40.7	123 56	420	91	66	86	64	81	62	22	20	
Buttonwillow	Kern	13	35.40	119 28	269	103	71	99	70	95	68	36	20	2621
Cabrillo NM	San Diego	7	32.70	117 14	410	89	69	84	68	80	67	12	39	
Cachuma Lake	Santa Barbara	5	34.59	119 59	781	97	69	92	67	87	65	19	26	
Calabasas	Los Angeles	9	34.20		1100	102	71	98	70	93	69	26	26	2348
Calaveras Big Trees	San Joaquin	12	38.29	120 19	4696	92	61	88	60	84	58	33	11	5848
Calexico	Imperial	15	32.70		12	114	74	110	73	106	71	28	26	
Callahan	Siskiyou	16	41.29	122 48	3185	97	63	93	62	88	60	35	7	
Calwa	Fresno	13	36.79		330	105	73	101	71	97	68	34	23	
Camarillo	Ventura	6	34.20	119 12	147	91	69	84	68	78	67	22	28	
Cambria AFS	San Luis	5	35.5	121 04	690	78	62	72	61	66	59	16	30	3646
Camp Pardee	Calaveras	12	38.20	120 51	658	106	71	103	70	98	69	36	27	2812
Camp Roberts	Monterey	4	35.79	120 45	765	106	72	101	71	95	69	45	16	2890
Campbell	Santa Clara	4	37.29	121 50	195	93	69	88	66	83	65	30	28	
Campo	San Diego	14	32.59	116 28	2630	101	67	95	66	90	66	41	16	3303
Canoga Park	Los Angeles	9	34.20	118 34	790	104	71	99	70	93	69	38	25	1884
Cantil	Kern	14	35.29	117 58	2010	111	71	107	71	103	70	32	12	
Canyon Dam	Plumas	16	40.09	121 05	4555	93	60	90	59	85	57	39	1	6834
Capitola	Santa Cruz	3	37		64	94	67	88	66	81	63	24	27	
Cardiff-by-the-Sea	San Diego	7	33		80	87	68	83	67	77	65	12	35	
Carlsbad	San Diego	7	33.20		44	87	68	83	67	77	65	10	34	
Carmel Valley	Monterey	3	36.5	121 44	425	94	68	88	66	80	65	20	25	
Carmichael	Sacramento	12	38.59	121 27	100	104	70	100	69	94	68	35	25	

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	Summer .1% Wet Bulb	Summer .5% Dry Bulb	Summer .5% Wet Bulb	Summer 2% Dry Bulb	Summer 2% Wet Bulb	Summer Range	Winter Minimum	HDD
Carpinteria	Santa Barbara	6	34.40		385	90	69	83	67	77	65	15	30	
Carson	Los Angeles	6	33.79		60	96	69	88	68	82	66	19	33	
Castle AFB	Merced	12	37.40	120 34	188	105	71	101	70	96	69	33	24	2590
Castro Valley	Alameda	3	37.59	122 12	177	93	67	87	67	80	65	25	24	
Catheys Valley	Mariposa	12	37.40	120 03	1000	102	69	99	68	94	67	38	21	
Cecilville	Siskiyou	16	41.09	123 08	3000	95	63	89	62	84	59	44	13	
Cedarville	Modoc	16	41.5	120 10	4670	97	61	94	60	89	58	35	1	6304
Centerville PH	Butte	11	39.79	121 40	522	105	70	100	68	96	67	40	25	2895
Ceres	Stanislaus	12	37.59		90	101	72	96	70	90	67	36	24	
Cerritos	Los Angeles	8	33.90		34	99	71	92	69	85	68	23	33	
Cherry Valley Dam	Tuolumne	10	38		4765	96	62	92	61	88	59	32	9	
Cherryland	Alameda	3	37.5		100	93	67	86	66	79	64	24	26	
Chester	Plumas	16	40.29	121 14	4525	94	62	91	61	86	59	33	-3	
Chico Exp Sta	Butte	11	39.70	121 47	205	105	70	102	69	96	68	37	22	2878
China Lake	San	14	35.70	117 41	2220	112	70	108	68	104	68	33	15	2560
Chino	San Bernardino	10	34		714	104	70	100	69	94	68	35	27	
Chula Vista	San Diego	7	32.59	117 05	9	90	70	84	68	79	66	9	33	2072
Citrus Heights	Sacramento	12	38.70	121 27	138	104	71	100	70	94	68	36	24	
Claremont	Los Angeles	9	34.09	117 43	1201	101	69	97	68	91	66	34	29	2049
Clarksburg	Yolo	12	38.40	121 32	14	102	70	97	69	91	67	35	24	2971
Clearlake Highlands	Lake	2	39	122 43	1360	101	69	97	68	89	65	36	15	
Cloverdale	Sonoma	2	38.79	122 59	320	102	70	97	69	89	66	37	26	2763
Clovis	Fresno	13	36.79	119 43	404	105	72	102	70	98	68	36	22	
Coachella	Riverside	15	33.70		-76	114	74	110	73	106	73	28	25	
Coalinga	Fresno	13	36.20	120 21	671	103	70	98	70	93	69	34	23	2592
Colfax	Placer	11	39.09	120 57	2418	100	66	97	65	92	63	29	22	3424
Colton	San Bernardino	10	34.09		978	105	70	102	68	97	67	35	28	
Colusa	Colusa	11	39.20	122 01	60	103	72	100	70	94	68	36	23	2793
Commerce	Los Angeles	8	33.90		175	98	69	92	68	86	67	23	33	
Compton	Los Angeles	8	33.90	118 13	71	97	69	90	68	83	67	21	33	1606
Concord	Contra Costa	12	38	112 00	195	102	70	97	68	89	65	34	27	3035
Corcoran	Kings	13	36.09	119 42	200	106	72	102	71	98	70	36	22	2666
Corona	Riverside	10	33.90	117 34	710	104	70	100	69	92	67	35	26	1794
Coronado	San Diego	7	32.70	117 10	20	89	69	82	67	76	65	10	36	1500
Corte Madera	Marin	2	37.90		55	97	68	91	66	84	64	34	28	
Costa Mesa	Orange	6	33.70	117 53	100	88	68	81	66	73	65	16	31	1482
Covelo	Mendocino	2	39.79	123 15	1385	99	67	93	65	87	63	43	15	4179
Covina	Los Angeles	9	34.09		575	101	70	97	69	91	68	34	29	
Crescent City	Del Norte	1	41.79	124 12	40	75	61	69	59	65	58	18	28	4445
Crockett	Contra Costa	12	38	122 13	9	96	68	90	66	85	64	23	28	
Crows Landing	Stanislaus	12	37.40	121 06	140	101	70	96	68	89	66	33	23	2767
Cucamonga	San Bernardino	10	34.09		1450	103	69	99	68	93	65	31	29	
Cudahy	Los Angeles	8	33.90		130	98	70	91	69	85	67	21	33	
Culver City	Los Angeles	8	34	118 24	106	96	70	88	69	83	67	18	35	1515
Cupertino	Santa Clara	4	37.29	122 00	70	96	68	88	67	80	64	30	28	
Cuyama	Santa Barbara	4	34.90	116 35	2255	99	68	96	67	89	66	42	13	
Cuyamaca	San Diego	7	33		4650	92	64	85	62	81	59	29	11	4848
Cypress	Orange	8	33.79		75	98	70	92	69	85	67	24	31	
Daggett AP	San Bernardino	14	34.90	116 47	1915	109	68	106	68	102	66	33	21	2203

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Daly City	San Mateo	3	37.59	122 30	410	84	65	78	62	73	61	16	34	
Davis	Yolo	12	38.5	121 46	60	103	72	99	70	93	68	41	24	2844
De Sabla	Butte	11	39.90	121 37	2713	97	66	94	64	88	62	35	18	4237
Death Valley	Inyo	14	36.5	116 52	-194	121	77	118	76	114	74	28	27	1147
Deep Springs Clg	Inyo	16	37.5	117 59	5225	98	60	95	59	92	58	35	-3	
Deer Creek PH	Nevada	16	39.29	120 51	4455	93	61	91	60	87	58	39	10	5863
Del Aire	Los Angeles	6	34		100	91	69	84	67	79	66	15	37	
Delano	Kern	13	35.79		323	106	71	102	70	98	69	36	22	
Denair	Stanislaus	12	37.59	120 47	137	100	70	95	69	89	67	38	22	2974
Diamond Bar	Los Angeles	9	34		880	101	69	97	68	92	66	33	28	
Dinuba	Tulare	13	36.5		340	104	73	101	70	96	69	36	24	
Dixon	Solano	12	38.40	121 51	100	104	72	99	70	93	68	36	24	2826
Dobbins	Yuba	11	39.40	121 12	1640	104	70	101	68	96	67	31	24	
Donner Mem Stt Pk	Nevada/Placer	16	39.29	120 15	5937	85	56	82	56	77	54	40	-3	
Donner Summit	Placer	16	39.40	120 20	7239	80	53	77	53	72	50	40	-8	8290
Downey	Los Angeles	8	33.90	118 00	110	98	71	90	70	84	68	21	32	
Downieville RS	Sierra	16	39.59	120 48	2895	98	64	95	63	90	61	42	13	
Doyle	Lassen	16	40	120 06	4390	96	63	93	62	88	59	42	0	
Dry Canyon Res	Ventura	16	34.5	118 32	1455	105	71	100	69	96	68	32	24	
Duarte	Los Angeles	9	34.09		500	100	69	96	68	90	67	33	31	
Dublin	Alameda	12	37.70	121 30	200	99	69	93	67	86	65	35	24	
Dudleys	Mariposa	12	37.70	120 06	3000	97	65	94	64	90	62	44	10	4959
Duttons Landing		2	38.2	122 18	20	96	68	91	66	84	64	31	26	
Eagle Mtn	Riverside	14	33.79	115 27	973	113	72	110	71	105	69	24	32	1138
East Los Angeles	Los Angeles	9	34	118 15	250	99	69	92	68	86	67	21	38	
East Park Res	Colusa	11	39.40	122 31	1205	101	69	97	68	92	66	38	19	3455
Edwards AFB	Kern	14	34.90	117 52	2316	107	69	104	68	99	66	35	10	3123
El Cajon	San Diego	10	32.70	116 57	525	96	70	91	69	87	67	30	29	
El Capitan Dam	San Diego	14	32.90	116 49	600	105	71	98	70	93	68	35	29	1533
El Centro	Imperial	15	32.79	115 34	-30	115	74	111	73	107	73	34	26	1212
El Cerrito	Contra Costa	3	37.79		70	91	66	84	64	75	62	17	30	
El Mirage	San Bernardino	14	34.59		2910	105	69	101	68	97	66	31	9	
El Monte	Los Angeles	9	34.09		271	101	71	97	70	91	68	30	31	
El Rio	Ventura	6	34.29		50	95	69	88	68	82	66	20	30	
El Segundo	Los Angeles	6	33.90		105	91	69	84	68	79	66	14	37	
El Toro MCAS	Orange	8	33.70	117 44	380	96	69	89	69	82	68	26	34	1591
Electra PH	Amador	12	38.29	120 40	715	106	70	102	69	98	68	41	23	2858
Elk Valley	Del Norte	16	42	123 43	1705	96	65	90	63	84	61	39	16	5404
Elsinore	Riverside	10	33.70	117 20	1285	105	71	101	70	98	69	39	22	2128
Encinitas	San Diego	7	33		50	87	68	83	67	77	65	10	35	
Enterprise	Shasta	11	40.59		470	107	69	103	68	97	67	29	26	
Escondido	San Diego	10	33.09	117 05	660	97	69	90	68	84	67	29	26	2005
Eureka	Humboldt	1	40.79	124 10	43	75	61	69	59	65	58	11	30	4679
Fair Oaks	Sacamento	12	38.70	121 16	50	104	70	100	69	94	69	36	23	
Fairfax	Marin	2	38		110	96	68	90	66	83	63	34	26	
Fairfield FS	Solano	12	38.29	122 02	38	103	69	98	68	91	66	34	24	2686
Fairmont	Los Angeles	14	34.70	118 26	3060	100	67	96	66	92	65	22	22	3330
Fallbrook	San Diego	10	33.59	117 15	660	94	68	89	67	85	66	29	26	2077
Ferndale	Humboldt	1	40.5	124 18	1445	76	57	66	56	62	54	12	28	

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						.1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range		
Fillmore	Verntura	9	34.40		435	100	70	94	69	87	67	30	28	
Five Points	Fresno	13	36.40	120 09	285	103	71	99	70	93	68	36	21	
Fleming Fish & Game	Lassen	16	40.40	120 19	4000	96	62	93	61	88	59	40	-3	
Florence-Graham	Los Angeles	8	34		175	98	69	90	68	84	67	19	35	
Florin	Sacramento	12	38.5		100	104	71	100	69	94	68	35	29	
Folsom Dam	Sacramento	12	38.70	121 10	350	104	70	101	69	95	67	36	25	
Fontana	San Bernardino	10	34.09	117 26	1090	105	70	101	69	97	67	33	30	1530
Forest Glen	Trinity	16	40.40	123 20	2340	96	65	92	64	88	62	42	12	
Fort Baker	Marin	3	37.79	122 28	15	87	66	81	65	73	65	12	33	3080
Fort Bidwell	Modoc	16	41.90	120 08	4498	93	60	90	59	85	57	38	-2	6381
Fort Bragg	Mendocino	1	39.5	123 49	80	75	60	67	59	62	58	15	29	4424
Fort Jones RS	Siskiyou	16	41.59	122 51	2725	98	64	93	63	88	61	44	5	5590
Fort MacArthur	San Diego	7	33.70	118 18	200	92	69	84	68	78	66	13	35	1819
Fort Ord	Monterey	3	36.70	121 46	134	86	65	77	63	70	60	18	24	3818
Fort Ross	Sonoma	1	38.5	123 15	116	79	63	74	62	65	59	19	30	4127
Foster City	San Mateo	3	37.5	122 14	20	92	67	84	65	76	63	22	29	
Fountain Valley	Orange	6	33.70		60	97	70	90	68	84	67	18	33	
Freedom	Santa Cruz	3	37		1495	89	67	85	64	79	62	22	27	
Fremont	Alameda	3	37.5	122 00	56	94	67	88	65	81	63	24	25	
Fresno AP	Fresno	13	36.79	119 43	328	104	73	101	71	97	68	34	24	2650
Friant Gov Camp	Fresno	13	37	119 43	410	106	72	103	70	100	68	40	23	2768
Fullerton	Orange	8	33.90		340	100	70	94	69	87	68	26	30	
Garden Grove	Orange	8	33.59		85	98	70	91	68	84	67	23	31	
Gardena	Los Angeles	8	33.90		40	92	69	85	68	80	66	18	32	
George AFB	San Bernardino	14	34.59	117 23	2875	105	67	102	65	98	62	31	19	2887
Georgetown RS	El Dorado	12	38.90	120 47	3001	98	64	95	63	90	61	31	18	
Giant Forest	Tulare	16	36.59	118 46	6412	84	56	81	55	77	53	26	5	
Gillespie Field	Solano	12	32.79		385	98	71	91	70	85	68	30	24	
Gilroy	Santa Clara	4	37	121 34	194	101	70	93	68	86	65	25	23	
Glen Avon	Riverside	10	34		827	105	70	101	69	95	67	35	28	
Glendale	Los Angeles	9	34.20		563	101	70	96	68	90	67	28	30	
Glendora	Los Angeles	9	34.09		822	102	69	98	68	92	67	35	30	
Glenville	Kern	16	35.70	118 44	3140	97	67	94	66	90	64	43	11	4423
Gold Rock Rch	Imperial	14	32.90		485	113	73	110	72	106	70	28	31	
Grant Grove	Tulare	16	36.70	118 58	6600	82	56	78	55	74	52	26	6	7044
Grass Valley	Nevada	11	39.20	121 04	2400	99	67	96	65	91	63	29	19	
Graton	Sonoma	2	38.40	122 52	200	95	68	91	67	82	64	34	22	3409
Grossmont	San Diego	7	32.70		530	96	69	89	68	84	66	23	31	
Grover City	San Luis	5	35.09		100	93	69	86	64	80	62	18	30	
Hacienda Hts	Los Angeles	9	34		300	100	69	96	68	90	67	28	31	
Haiwee	Inyo	16	36.09	117 57	3825	102	65	99	64	95	62	27	15	3700
Half Moon Bay	San Mateo	3	37.5	122 26	60	83	64	76	62	69	59	15	32	3843
Hamilton AFB	Marin	2	38.09	122 30	3	95	69	88	67	81	65	28	27	3311
Hanford	Kings	13	36.29	119 40	242	102	71	99	70	94	68	37	22	2736
Happy Camp RS	Siskiyou	16	41.79	123 22	1150	103	67	97	66	92	65	41	18	4263
Hat Creek PH 1	Shasta	16	40.90	121 33	3015	99	65	96	64	91	62	48	2	5689
Hawaiian Gardens	Los Angeles	8	33.79		75	97	70	91	69	84	67	23	32	
Hawthorne	Los Angeles	8	33.90		70	92	69	85	68	80	66	16	37	
Hayfield Pumps	Riverside	14	33.70	115 38	1370	112	71	108	70	104	68	31	24	1529

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	Summer .1% Wet Bulb	Summer .5% Dry Bulb	Summer .5% Wet Bulb	Summer 2% Dry Bulb	Summer 2% Wet Bulb	Summer Range	Winter Minimum	HDD
Hayward	Alameda	3	37.70	122 07	530	92	66	86	65	81	62	24	26	2909
Healdsburg	Sonoma	2	38.59	122 52	102	102	69	95	68	90	66	37	26	2572
Hemet	Riverside	10	33.70		1655	109	70	104	69	101	67	40	20	
Henshaw Dam	San Diego	10	33.20		2700	99	68	94	67	90	66	38	15	3708
Hermosa Beach	Los Angeles	6	33.90		16	92	69	84	68	78	66	12	38	
Hetch Hetchy	Tuolomne	16	38	119 47	3870	93	62	89	61	85	59	32	14	4816
Highland	San Bernardino	10	34.09		1315	106	70	102	69	97	68	36	26	
Hillcrest Center	Kern or Shasta	0	35.40		500	106	71	102	70	98	68	34	26	
Hillsborough	San Mateo	3	37.59	122 18	352	90	66	82	65	74	64	23	30	
Hilts	Siskiyou	16	42	122 38	2900	97	64	93	62	89	60	39	5	
Hollister	San Benito	4	36.90	121 25	280	96	68	89	67	81	65	30	21	2725
Hollywood	Los Angeles	9	34	118 23	384	96	70	89	69	83	67	20	36	
Hoopa	Humboldt	2	41	123 40	360	100	67	92	66	87	64	25	23	
Huntington Beach	Orange	6	33.70	117 48	40	91	69	83	67	76	66	14	34	
Huntington Lake	Fresno	16	37.20	119 13	7020	80	55	77	54	73	51	25	3	7632
Huntington Park	Los Angeles	8	34	118 00	175	98	70	90	69	84	67	20	38	
Idlewild	Del Norte	1	41.90	124 00	1250	103	68	96	66	92	65	40	18	
Idria	San Benito	4	36.40	120 40	2650	97	66	92	65	87	62	27	24	3128
Idyllwild	Riverside	16	33.70	116 43	5397	93	62	89	61	84	60	35	9	
Imperial AP	Imperial	15	32.79	115 34	-59	114	74	110	73	106	72	31	26	1060
Imperial Beach	San Diego	7	32.5	117 07	23	87	69	82	68	78	67	10	35	1839
Imperial CO	Imperial	16	32.90		-64	112	73	108	72	104	71	31	29	976
Independence	Inyo	16	36.79		3950	104	61	101	60	97	60	31	12	
Indio	Riverside	15	33.70	116 15	11	115	75	112	75	107	74	30	24	1059
Inglewood	Los Angeles	8	33.90	118 00	105	92	68	85	67	80	65	15	37	
Inyokern NAS	Kern	14	35.70	117 49	2440	110	71	106	68	102	66	37	15	2772
Iron Mtn	Shasta	11	34.09	115 08	922	116	75	112	74	108	73	26	29	1251
Irvine	Orange	8	33.70	118 00	50	96	69	88	68	82	67	27	33	
Isla Vista	Santa Barbara	6	34.5		40	90	69	83	67	77	65	20	33	
Jess Valley	Modoc	16	41.29		5300	92	59	89	58	84	56	35	-7	7045
John Wayne AP	Orange	7	33.59		115	98	70	91	68	84	67	26	33	1496
Julian Wynola	San Diego	14	33.09	116 48	3650	96	66	91	64	87	62	39	20	4049
Kentfield	Marin	2	38	122 33	120	97	66	91	65	84	63	35	27	3009
Kern River PH 1	Kings	13	35.5	118 47	970	106	72	103	71	99	69	26	30	1878
Kern River PH 3	Kern	16	35.79	118 34	2703	103	69	100	68	96	66	34	19	2891
Kettleman Stn	Kings	13	36.09	120 05	508	104	71	100	70	93	68	31	26	2180
King City	Monterey	4	36.20	121 08	320	94	67	90	65	85	64	36	20	2639
Klamath	Del Norte	1	41.5	124 05	25	79	62	71	60	66	58	18	26	4509
Knights Ferry	Stanislaus	12	37.79	120 34	315	103	70	99	68	94	67	37	19	
La Canada-Flintridge	Los Angeles	9	34.20	118 00	1365	99	69	95	68	88	66	30	32	
La Crescenta-Montrose	Los Angeles	9	34.20	118 00	1565	98	69	94	68	87	66	33	31	
La Habra	Orange	8	33.90	118 00	305	100	69	94	68	87	67	27	30	
La Mesa	San Diego	7	32.79	117 01	530	94	70	88	69	84	67	23	34	1567
La Mirada	Los Angeles	9	33.90	118 00	115	99	70	91	69	85	68	26	31	
La Palma	Orange	8	33.90	118 00	75	98	69	92	68	85	67	25	31	
La Puente	Los Angeles	9	34	118 00	320	101	71	97	70	91	69	28	31	
La Verne	Los Angeles	9	34.09	118 00	1235	101	69	97	68	91	67	34	29	
Lafayette	Contra Costa	12	37.90	122 08	535	100	69	94	67	87	66	32	24	
Laguna Beach	Orange	6	33.5	117 47	35	91	69	83	68	76	66	18	30	2222

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer							Winter Minimum	HDD
						.1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range		
Lake Arrowhead	San Bernardino	16	34.2	117 11	5205	90	62	86	61	81	59	26	13	5310
Lake Spaulding	Nevada	16	39.29	120 38	5156	89	58	86	57	83	55	34	3	6447
Lakeport	Lake	2	39	122 55	1347	97	67	93	66	88	63	41	20	3728
Lakeshore	Fresno	16	40.90		1075	104	69	100	68	95	66	28	29	
Lakeside	San Diego	10	32.79	117 00	690	95	69	90	68	86	66	20	26	
Lakewood	Los Angeles	8	33.90	118 00	45	98	70	90	68	84	66	22	33	
Lamont	Kern	13	35.29	120 00	500	106	72	102	71	98	69	34	26	
Lancaster	Los Angeles	14	34.70	118 12	2340	106	68	102	67	98	66	35	12	
Larkspur	Marin	2	37.90	122 30	20	97	68	91	66	84	64	34	28	
Las Plumas	Butte	11	39.70		506	104	71	101	70	96	68	32	24	
Lava Beds	Siskiyou	16	41.70	121 31	4770	93	59	89	58	84	56	41	-1	
Lawndale	Los Angeles	8	33.90	118 00	66	92	69	85	68	80	66	16	37	
Le Grand	Merced	12	37.20	120 15	255	101	70	96	68	91	66	38	23	2696
Lemon Grove	San Diego	7	32.70	117 12	437	96	71	88	69	84	67	19	34	
Lemoncove	Tulare	13	36.40	119 02	513	105	72	102	70	98	68	38	25	2513
Lemoore NAS	Kings	13	36.29	119 57	228	104	72	101	71	97	69	37	19	2960
Lennox	Los Angeles	8	33.90	117 45	71	92	69	85	68	80	66	16	37	
Lindsay	Tulare	13	36.20	119 04	395	105	72	101	71	97	69	40	24	2634
Little Panoche	Fresno	13	36.79		677	100	68	94	67	86	66	33	23	
Livermore	Alameda	12	37.70	121 57	490	100	69	95	68	88	67	35	22	3012
Llano Shawnee	Los Angeles	14	34.5	117 45	3820	104	68	99	67	95	65	31	21	
Lodgepole	Lassen	16	36.59	118 43	6735	84	57	80	56	78	54	26	-4	
Lodi	San Joaquin	12	38.09	121 17	40	101	70	97	68	91	67	38	23	2859
Loma Linda	San Bernardino	10	34	117 30	1150	106	70	103	69	99	67	36	27	
Lomita	Los Angeles	6	33.79	119 00	56	95	69	87	68	81	66	18	33	
Lompoc	Santa Barbara	5	34.90	120 27	95	84	63	77	62	72	60	18	26	2888
Long Beach AP	Los Angeles	6	33.79	118 14	25	99	71	90	69	84	66	21	33	1606
Long Beach CO	Los Angeles	6	33.70	118 09	34	97	70	88	68	82	65	18	35	
Los Alamitos NAS	Orange	8	33.79	118 03	30	98	71	89	69	83	68	23	32	1740
Los Altos	Santa Clara	4	37.29	122 00	163	96	68	88	65	80	62	26	28	
Los Angeles AP	Los Angeles	6	33.90	118 24	97	91	67	84	67	79	66	14	37	1819
Los Angeles CO	Los Angeles	9	34	118 14	270	99	69	92	68	86	67	21	38	1245
Los Banos	Merced	12	37	120 52	120	100	70	96	68	88	67	42	22	2616
Los Banos Res	Merced	12	37	120 52	407	101	70	97	68	89	67	42	23	
Los Gatos	Santa Clara	4	37.20	121 58	365	98	69	90	67	82	66	32	26	2741
Lucerne Valley	San Bernardino	14	34.5	116 57	2957	105	67	101	66	98	64	38	12	
Lynwood	Los Angeles	8	33.90	118 00	88	98	70	90	69	83	67	21	32	
Madera	Madera	13	37	120 04	268	105	72	101	70	96	68	40	24	2673
Manhattan Beach	Los Angeles	6	33.90	118 00	120	91	69	84	68	79	66	12	38	
Manteca	San Joaquin	12	37.79	121 12	34	102	70	97	68	91	67	37	24	
Manzanita Lake	Shasta	16	40.5	121 34	5850	87	58	84	57	79	55	34	-3	7617
March AFB	Riverside	10	33.90	117 15	1511	103	70	99	68	94	65	34	23	2089
Maricopa	Kern	13	35.09	119 23	675	106	71	102	70	98	68	29	25	2302
Marina	Monterey	3	36.70		20	86	66	77	63	70	61	18	32	
Markley Cove		2	38.5	122 07	480	104	70	99	69	93	67	39	23	
Martinez FS	Contra Costa	12	38	122 08	40	99	67	94	66	88	65	36	28	
Marysville	Yuba	11	39.20	121 35	60	105	72	102	70	97	68	36	27	2552
Mather AFB	Sacramento	12	38.59	121 18	96	104	71	100	70	94	68	35	28	
Maywood	Los Angeles	8	34	118 00	170	97	70	91	69	85	67	21	34	

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range	Winter Minimum	HDD
McClellan AFB	Sacramento	12	38.70	121 24	86	105	71	102	70	96	68	35	23	2566
McCloud	Siskiyou	16	41.29	122 08	3300	96	63	93	62	87	60	42	5	5990
Mecca FS	Riverside	15	33.59	116 04	-180	115	75	111	75	107	74	30	24	1185
Menlo Park	San Mateo	3	37.40	122 20	65	94	67	86	65	78	63	25	27	
Merced AP	Merced	12	37.29	120 34	153	103	71	100	69	95	67	36	21	2653
Mill Creek	Tehama	16	35.09	117 01	2940	102	67	97	66	94	65	28	28	
Mill Valley	Marin	3	37.90	122 35	80	97	68	91	66	84	64	28	28	3400
Millbrae	San Mateo	3	37.59	122 21	10	90	66	82	63	74	61	24	30	
Milpitas	Santa Clara	4	37.40	121 54	15	94	68	87	65	79	63	27	27	
Mineral	Tehama	16	40.40	121 36	4911	90	60	87	59	82	57	38	2	7257
Miramir AFS	San Diego	7	32.90	117 08	477	97	69	91	68	86	67	22	32	1532
Mission Viejo	Orange	8	33.59	118 00	350	95	67	87	66	81	63	22	33	
Mitchell Caverns	San Berardino	14	34.90		4350	102	64	98	63	94	61	29	21	
Modesto	Stanislaus	12	37.59	121 00	91	102	73	99	70	95	68	36	25	2671
Moffett Field NAS	Santa Clara	4	37.40	122 03	39	89	68	84	66	78	64	23	30	2511
Mojave	Kern	14	35.09	118 11	2735	106	68	102	67	98	66	35	16	3012
Mono Lake	Mono	16	38	119 09	6450	91	58	88	57	84	55	32	4	6518
Monrovia	Los Angeles	9	34.20	118 18	562	100	69	96	68	90	67	30	33	
Montague	Siskiyou	16	41.79	122 28	2648	99	66	95	65	90	63	39	3	5474
Montclair	San Bernardino	10	34	117 00	1220	104	69	100	68	94	66	35	28	
Montebello	Los Angeles	9	34	118 06	205	98	69	93	68	86	67	24	33	
Monterey AP	Monterey	3	36.59	121 52	245	86	65	77	62	70	61	20	30	3556
Monterey CO	Monterey	3	36.59	121 52	345	87	65	78	62	71	61	20	32	3169
Monterey Park	Los Angeles	9	34	118 00	380	99	69	94	68	87	67	23	30	
Monticello Dam	Solano	2	38.5	122 07	505	105	71	100	70	94	68	39	26	
Moraga	Contra Costa	12	37.79	122 10	600	99	68	93	66	86	64	27	21	
Morgan Hill	Santa Clara	4	37.09	120 00	350	100	69	92	68	85	66	25	26	
Morro Bay FD	San Luis	5	35.40	120 51	115	88	65	82	64	76	62	14	31	
Mount Baldy Notch	San Bernardino	16	34.29	117 37	7735	80	58	76	57	71	54	32	4	
Mount Diablo	Contra Costa	12	37.90	121 55	2100	101	68	96	66	87	65	28	27	4600
Mount Hamilton	Santa Clara	4	37.29	121 39	4206	95	59	88	58	81	56	18	18	4724
Mount Hebron RS	Siskiyou	16	41.79	122 01	4250	92	60	88	59	82	57	42	-10	
Mount San Jacinto	Riverside	16	33.79	116 38	8417	82	56	77	55	73	53	35	-1	
Mount Shasta	Siskiyou	16	41.29	122 19	3535	93	62	89	61	84	59	34	8	5890
Mount Wilson	Los Angeles	16	34.20	118 04	5709	90	63	85	61	79	58	21	15	4296
Mountain Pass	San Bernardino	14	35.5	115 32	4730	100	65	96	64	92	63	29	11	
Mountain View	Santa Clara	4	37.5	121 54	95	93	67	85	64	77	62	25	28	
Nacimiento Dam	San Luis	4	35.79	120 53	770	100	68	94	66	88	64	35	22	
Napa State Hospital	Napa	2	37.29	122 16	60	94	67	91	67	86	66	29	26	2749
National City	San Diego	7	32.70	117 00	34	87	70	82	68	78	66	10	36	
Needles AP	San Bernardino	15	34.79	114 37	913	117	73	114	72	110	71	26	27	1391
Nevada City	Nevada	11	39.29	121 01	2600	97	66	94	64	88	63	41	14	4900
Newark	Alameda	3	37.5	122 02	10	94	68	89	67	82	65	24	29	
Newhall Soledad	Los Angeles	9	34.40	118 33	1243	104	70	100	68	95	67	42	27	
Newman	Stanislaus	12	37.29	121 03	90	104	71	99	69	93	67	38	22	
Newport Beach	Orange	6	33.59	117 53	10	87	68	80	66	72	65	12	34	1952
Norco	Riverside	10	33.90	117 00	700	103	70	99	69	94	67	34	27	
North Fork RS	Madera	16	37.20	119 30	2630	98	66	95	65	92	62	36	15	
North Highlands	Sacramento	12	38.59	121 25	45	104	71	100	69	94	67	35	23	2566

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range	Winter Minimum	HDD
North Hollywood	Los Angeles	9	34.20	118 23	619	102	70	97	69	91	67	31	28	
Norwalk	Los Angeles	8	33.9		97	99	69	90	68	84	67	26	31	
Novato	Marin	2	38.09	122 31	370	94	64	87	63	80	61	30	25	
Oakdale	Stanislaus	12	37.79	120 52	215	102	71	99	69	93	67	37	22	
Oakland AP	Alameda	3	37.70	122 12	6	91	66	84	64	77	62	20	32	2909
Oakland Museum	Alameda	3	37.79	122 10	30	96	68	89	66	82	63	20	31	
Oceanside	San Diego	7	33.20	117 24	10	84	69	80	67	74	65	10	33	
Oildale	Kern	13	35.5	119 00	450	106	71	102	70	98	68	34	26	
Ojai	Ventura	9	34.5	119 15	750	102	71	97	69	91	68	38	25	2145
Ontario AP	San Bernardino	10	34	117 00	934	105	70	101	69	95	66	34	26	1710
Orange	Orange	8	33.59	118 00	194	99	70	92	68	85	67	27	33	
Orange Cove	Fresno	13	36.59	119 18	431	104	71	100	69	97	68	38	25	2684
Orangevale	Sacramento	12	38.70	121 12	140	105	72	102	70	96	68	36	24	
Orick Prairie Creek	Humboldt	1	41.40	124 01	161	80	61	75	60	70	59	23	25	4816
Orinda	Contra Costa	12	37.90	122 10	550	99	68	93	66	86	64	32	21	
Orland	Glenn	11	39.79	122 12	254	105	71	102	70	97	68	36	22	2824
Orleans	Humboldt	2	41.29	123 32	403	104	70	97	68	91	66	42	21	3628
Oroville RS	Butte	11	39.5	121 33	300	106	71	104	70	98	69	37	25	
Otay-Castle Pk	San Diego	7	32.59	117 00	500	87	68	81	66	74	63	10	33	
Oxnard AFB	Ventura	6	34.20	119 11	49	94	69	86	68	79	67	21	30	2068
Pacific Grove	Monterey	3	36.70	122 00	114	87	66	78	63	71	61	19	31	
Pacifica	San Mateo	3	37.59	122 00	13	87	65	79	62	71	60	16	31	
Palm Desert	Riverside	15	33.70	116 30	200	116	74	112	73	108	72	34	26	
Palm Springs	Riverside	15	33.79	116 32	411	117	74	113	73	109	72	35	26	1109
Palmdale AP	Los Angeles	14	34.59	118 06	2517	107	67	103	67	98	64	33	12	2929
Palmdale CO	Los Angeles	14	34.59	118 06	2596	106	67	102	67	97	64	35	13	2908
Palo Alto	Santa Clara	4	37.5	122 08	25	93	66	85	64	77	62	25	26	2891
Palomar Obsy	San Diego	14	33.40	116 52	5545	90	62	85	61	80	59	22	16	4141
Palos Verdes	Los Angeles	6	33.79	119 00	216	92	69	84	68	78	66	14	38	
Paradise	Butte	11	39.79	121 36	1750	102	69	99	67	94	66	34	25	
Paramount	Los Angeles	8	33.90	117 00	70	98	70	90	69	84	67	22	32	
Parker Res	San Bernardino	15	34.29	114 10	738	115	74	112	73	108	72	26	32	1223
Pasadena	Los Angeles	9	34.20	118 09	864	99	69	94	68	88	67	30	32	1551
Paso Robles AP	San Luis	4	35.70	120 41	815	104	66	97	66	92	65	40	19	2973
Paso Robles CO	San Luis	4	35.59	120 41	700	102	65	95	65	90	65	44	16	2885
Pendleton MCB	San Diego	7	33.29	117 18	63	92	68	87	67	81	66	22	34	1532
Pendleton MCB Coast	San Diego	7	33.20	117 24	24	84	69	80	67	75	65	10	39	1782
Perris	Riverside	10	33.79	117 13	1470	105	70	101	69	97	68	39	22	
Petaluma FS 2	Sonoma	2	38.20	122 38	16	98	69	92	67	85	66	31	24	2959
Pico Rivera	Los Angeles	9	34	118 00	180	98	70	91	69	85	67	24	31	
Piedmont	Alameda	3	37.79	122 00	325	96	68	89	66	82	63	23	31	
Pinnacles NM	San Bernardino	14	36.5	121 11	1307	98	68	94	67	89	64	45	20	2956
Pinole	Contra Costa	3	38	122 18	10	91	66	87	65	82	64	25	30	
Pismo Beach	San Luis	5	35.09	120 37	80	92	66	85	64	80	62	16	30	2756
Pittsburg	Contra Costa	12	38	121 48	50	102	70	97	68	90	67	34	26	
Placentia	Orange	8	33.90	118 00	323	101	69	93	68	87	67	28	30	
Placerville	El Dorado	12	38.70	120 48	1890	101	67	98	66	93	65	42	20	4086
Placerville IFG	El Dorado	12	38.70	120 48	2755	100	66	97	65	92	64	42	23	
Platina	Shasta	11	40.40	122 53	2260	96	65	92	64	87	61	36	13	

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer							Winter Minimum	HDD
						.1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range		
Pleasant Hill	Contra Costa	12	37.90	122 00	102	96	68	93	67	88	65	34	25	
Pleasanton	Alameda	12	37.59	121 47	350	97	68	94	67	89	65	35	24	
Point Arena	Mendocino	1	38.90	123 44	100	76	62	72	60	67	58	19	29	4747
Point Arguello	Santa Barbara	5	34.59	120 40	76	75	64	71	63	65	59	17	29	3826
Point Mugu	Ventura	6	34.09	119 07	14	88	68	81	67	75	66	15	33	2328
Point Piedras Blancas	San Luis	5	35.70	121 17	59	73	60	67	59	61	57	10	36	3841
Pomona Cal Poly	Los Angeles	9	34.09	117 49	740	102	70	98	69	93	67	36	27	1971
Port Chicago ND	Contra Costa	12	38	122 01	50	98	69	94	68	88	66	34	28	
Port Hueneme	Ventura	6	34.20	119 00	13	88	68	81	67	75	66	15	33	2334
Porterville	Tulare	13	36.09	119 01	393	106	71	102	70	97	69	36	25	2456
Portola	Plumas	16	39.79	120 28	4850	92	63	89	61	84	59	48	-9	7111
Posey 3 E	Tulare	13	35.79	119 00	4960	89	62	86	61	82	59	26	9	
Potter Valley PH	Mendocino	2	39.40	123 08	1015	101	68	96	67	89	65	40	20	3276
Poway Valley	San Diego	10	33	117 00	500	100	70	94	69	89	68	26	29	
Priest Valley	Monterey	4	36.20	120 42	2300	97	66	93	65	88	63	34	13	4144
Quincy	Plumas	16	39.90	120 56	3409	101	64	98	63	93	62	45	1	5763
Ramona Spaulding	San Diego	10	33.09	116 49	1480	103	70	97	69	92	68	40	22	
Rancho Cordova	Sacramento	12	38.59	121 18	190	104	72	100	69	94	68	35	26	
Rancho Palos Verdes	Los Angeles	6	33.70	118 10	216	92	69	84	68	78	66	14	38	
Randsburg	Kern	14	35.29	117 39	3570	105	67	102	66	97	65	30	19	2922
Red Bluff AP	Tehama	11	40.20	122 15	342	107	70	104	69	98	66	31	24	2688
Redding FS 4	Shasta	11	40.59	122 24	470	107	69	103	68	97	67	30	26	2544
Redlands	San Bernadino	10	34.09	117 11	1318	106	70	102	69	98	67	34	27	1993
Redondo Beach	Los Angeles	6	33.79	118 19	45	92	69	84	68	78	66	12	37	
Redwood City	San Mateo	3	37.5	122 14	31	90	67	86	66	81	64	28	28	2599
Reedley	Fresno	13	36.59	119 42	344	104	71	101	70	96	68	40	24	
Rialto	San Bernardino	10	34.09	117 00	1254	105	70	101	69	96	66	35	28	
Richardson Grove	Humbolt	2	40	123 47	500	96	67	92	66	87	64	28	25	
Richmond	Contra Costa	3	37.90	121 36	55	88	65	84	64	77	62	17	31	2684
Ridgecrest	Kern	14	35.59	117 48	2340	110	70	106	68	102	66	35	15	
Riverside Exp Sta	Riverside	10	34	117 23	986	106	71	102	69	97	67	36	29	
Riverside FS 3	Riverside	10	34	117 23	840	104	70	100	69	95	65	37	27	1818
Rocklin	Placer	11	38.79	121 14	239	108	72	104	70	99	69	39	20	3143
Rohnert Park	Sonoma	2	38.40	122 33	106	99	69	96	68	92	66	33	24	
Rolling Hills	Los Angeles	6	33.59	119 00	216	92	69	84	68	78	66	15	38	
Rosemead	Los Angeles	9	34	118 00	275	98	70	90	69	84	67	27	30	
Roseville	Placer	11	38.70	121 13	160	105	71	102	70	96	68	36	24	
Rossmoor	Orange	8	33.79		20	92	67	85	64	79	62	19	32	
Rowland Hts	Los Angeles	9	33.90	118 00	540	99	70	93	69	86	68	27	29	
Rubidoux	Riverside	10	34	117 00	792	106	71	102	70	97	68	36	27	
Sacramento AP	Sacramento	12	38.5	121 30	17	104	72	100	70	94	68	35	26	2843
Sacramento CO	Sacramento	12	38.59	121 30	84	104	71	100	70	94	68	32	30	
Saint Helena	Napa	2	38.5	122 28	225	102	70	98	69	93	67	40	22	2878
Saint Mary's College	Contra Costa	12	37.79	122 07	623	98	69	93	68	86	66	28	21	3543
Salinas 3 E	Monterey	3	36.70	121 36	85	86	66	83	65	79	62	20	26	
Salinas AP	Monterey	3	36.70	121 36	69	85	67	82	65	78	62	20	28	2959
Salt Springs PH	Amador/Calavar	16	38.5	120 13	3700	95	62	92	61	87	59	27	19	3857
Salyer RS	Trinity	16	40.90	123 34	623	102	69	95	67	87	64	33	22	
San Anselmo	Marin	2	38	122 00	50	95	67	89	66	82	65	32	26	

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer							Winter Minimum	HDD
						.1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range		
San Antonio Canyon	Los Angeles	16	34.20	117 40	2394	100	68	96	67	90	65	33	29	
San Antonio Mission	Monterey	4	36	117 40	1060	99	69	94	68	88	67	28	19	
San Bernardino	San Bernardino	10	34.1	117 19	1125	106	70	102	69	98	68	39	27	1777
San Bruno	San Mateo	3	37.7	122 25	20	86	66	80	64	73	62	23	30	3042
San Carlos	San Mateo	3	37.5		26	92	67	88	65	82	63	28	28	
San Clemente	Orange	6	33.40	118 35	208	91	68	85	67	80	66	12	31	
San Diego AP	San Diego	7	32.70	117 10	13	88	70	83	69	78	68	13	38	1507
San Dimas	Los Angeles	9	34		955	102	70	98	69	92	67	35	30	
San Fernando	Los Angeles	9	34.29	118 28	977	104	71	99	70	94	68	37	30	1800
San Francisco AP	San Francisco	3	37.59	122 23	8	89	66	83	64	74	61	20	31	3042
San Francisco CO	San Francisco	3	37.79	122 25	52	84	65	79	63	71	60	14	38	3080
San Gabriel FD	Los Angeles	9	34.09	118 06	450	99	70	94	69	88	68	30	30	1532
San Gregorio 2 SE	San Mateo	3	37.29		275	87	66	81	63	74	61	30	27	
San Jacinto	Riverside	10	33.79	116 58	1535	110	70	105	69	102	68	41	20	2376
San Jose	Santa Clara	4	37.40	121 56	67	94	68	86	66	78	64	26	29	2438
San Leandro	Alameda	3	37.70		45	89	67	83	64	76	62	22	28	
San Lorenzo	Alameda	3	37.70		45	89	67	83	64	76	62	23	28	
San Luis Dam	Merced	12	37.09		277	97	68	91	66	86	64	32	25	
San Luis Obispo	San Luis	5	35.29	120 43	320	94	63	87	63	81	62	26	30	2498
San Marino	Los Angeles	9	34.20		300	100	69	95	68	88	66	28	30	
San Mateo	San Mateo	3	37.5	122 18	21	92	67	84	65	76	63	24	31	2655
San Nicholas Island	Ventura	6	33.20	119 28	504	85	66	78	65	70	64	11	39	2454
San Pablo	Contra Costa	3	37.59		30	90	65	84	63	77	61	17	29	
San Pedro	Los Angeles	6	33.70	118 16	10	92	69	84	68	78	66	13	35	1819
San Rafael	Marin	2	38	122 33	40	96	67	90	65	83	63	29	30	2440
Sandberg	Los Angeles	16	34.79	118 44	4517	95	63	91	61	87	59	32	17	4427
Sanger	Fresno	13	36.70		364	105	72	101	70	96	68	37	24	
Santa Ana FS	Orange	8	33.79	117 50	115	98	70	91	68	84	67	26	33	1430
Santa Barbara AP	Santa Barbara	6	34.40	119 50	9	90	69	83	67	77	65	20	29	2487
Santa Barbara CO	Santa Barbara	6	34.40	119 41	5	91	69	84	67	78	65	22	33	1994
Santa Clara Univ	Santa Clara	4	37.40	121 56	88	90	67	87	65	82	63	30	29	2566
Santa Cruz	Santa Cruz	3	37	122 01	125	94	68	88	66	81	64	28	27	3136
Santa Fe Springs	Los Angeles	9	33.90		280	99	69	90	68	84	67	24	31	
Santa Maria AP	Santa Barbara	5	34.90	120 27	236	90	66	83	64	78	61	23	25	3053
Santa Monica	Los Angeles	6	34	118 30	15	85	67	78	66	72	64	15	39	1873
Santa Paula	Ventura	9	34.40		263	101	71	94	70	87	68	28	28	2030
Santa Rosa	Sonoma	2	38.5	122 49	167	99	69	96	68	92	66	35	24	2980
Santee	San Diego	10	32.79		400	96	69	91	68	87	67	20	25	
Saratoga	Santa Clara	4	37.29		500	96	67	88	66	80	65	31	27	
Sausalito	Sonoma	3	37.90		10	85	66	80	65	73	63	12	30	
Sawyer's Bar RS	Siskiyou	16	41.29		2169	100	66	95	65	88	62	38	14	4102
Scotia	Humboldt	1	40.5	124 22	139	78	61	74	60	69	58	19	28	3954
Seal Beach	Orange	6	33.79	118 05	21	94	69	86	68	80	65	15	35	1519
Seaside	Monterey	4	36.59		17	85	66	79	64	73	62	20	30	
Selma	Fresno	13	36.59		305	104	73	101	71	97	68	38	24	
Shafter	Kern	13	35.5	119 10	345	106	71	102	70	98	68	28	24	2185
Shasta Dam	Shasta	16	40.70		1076	105	69	101	68	95	67	27	29	2943
Shelter Cove	Humboldt	1	40	124 04	110	80	61	73	60	68	57	15	34	
Sierra City	Sierra	16	39.59	120 07	4230	96	62	93	61	89	59	43	12	

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range	Winter Minimum	HDD
Sierra Madre	Los Angeles	9	34.20		1153	102	69	96	68	90	67	27	32	
Sierraville RS	Sierra	16	39.59	120 22	4975	94	60	91	59	86	57	44	-10	6893
Signal Hill	Los Angeles	6	33.5		100	99	70	90	69	84	66	19	35	
Simi Valley	Ventura	9	34.40		500	98	70	93	68	87	66	30	28	
Sonoma	Sonoma	2	38.29		70	101	70	96	69	90	67	40	22	2998
Sonora RS	Tuolumne	12	38	120 23	1749	103	68	100	67	95	66	34	20	3537
South El Monte	Los Angeles	9	34		270	101	72	97	70	91	68	28	31	
South Entr Yosemite	Tuolumne	16	37.5	119 38	5120	92	61	88	60	84	59	36	8	5789
South Gate	Los Angeles	8	33.90		120	97	70	90	69	84	67	21	32	
South Lake Tahoe	El Dorado	16	38.90		6200	85	56	82	55	71	54	33	-2	
South Pasadena	Los Angeles	9	34		657	99	69	94	68	88	67	30	31	
South San Francisco	San Mateo	3	37.70		10	87	67	81	64	72	62	20	32	
South Whittier	Los Angeles	9	33.90		300	100	70	92	69	84	68	30	31	
Spring Valley	San Diego	10	32.70		300	94	69	86	68	82	66	30	34	
Squaw Valley	Placer	16	39.20		6235	88	57	85	56	80	54	40	-10	
Squirrel Inn	San Bernardino	14	34.20	117 14	5680	86	61	82	60	77	58	23	12	5175
Stanton	Orange	8	33.59		45	98	69	91	68	84	67	24	31	
Stockton AP	San Joaquin	12	37.90	121 15	22	103	71	98	69	93	67	35	24	2806
Stockton FS 4	San Joaquin	12	38	121 19	12	101	70	96	68	91	67	37	24	2846
Stony Gorge Res	Glenn	11	39.59	122 32	791	104	70	99	69	93	67	37	21	3149
Strawberry Valley	Tuolumne	16	39.59		3808	96	63	93	62	88	60	32	14	5120
Sunland	Los Angeles	9	34.29		1460	107	71	102	70	96	68	36	28	
Sunnyvale	Santa Clara	4	37.29	122 02	97	96	68	88	66	80	64	26	29	2511
Susanville AP	Lassen	16	40.40	120 34	4148	98	62	95	61	90	59	38	-1	6233
Tahoe City	Placer	16	39.20	120 08	6230	84	56	81	55	76	53	36	2	8085
Tahoe Valley AP	Placer	16	38.90		6254	85	56	82	55	77	53	38	-5	
Tehachapi	Kern	16	35.09		3975	97	66	93	65	89	64	33	13	4494
Tejon Rancho	Los Angeles	16	35	118 45	1425	107	71	103	70	99	68	27	24	2602
Temple City	Los Angeles	9	34.09		403	101	70	95	69	89	68	27	30	
Termo	Los Angeles	16	40.90		5300	95	60	92	59	87	57	37	-17	
Thermal AP	Riverside	15	33.59		-112	114	74	110	74	106	74	29	26	1154
Thousand Oaks	Ventura	9	34.20		810	98	69	93	68	88	67	30	27	
Three Rivers PH 1	Tulare	13	36.5		1140	105	70	102	69	98	67	38	24	2642
Tiburon	Marin	3	37.90		90	85	66	80	65	73	63	12	30	
Tiger Creek PH	Amador	12	38.5	120 29	2355	100	66	96	55	92	63	36	20	3795
Torrance	Los Angeles	6	33.79	118 20	110	93	69	86	68	80	66	18	32	1859
Tracy Carbona	San Joaquin	12	37.70		140	102	70	97	68	90	67	38	24	2704
Tracy Pumps	San Joaquin	12	37.79		61	104	71	99	69	92	68	39	23	
Travis AFB	Sonoma	12	38.29	121 56	72	103	71	98	69	91	66	35	24	2725
Trinity Dam	Trinity	16	40.79		2500	99	65	94	64	88	62	37	17	
Trona	San Bernardino	14	35.79	117 23	1695	113	72	109	70	105	68	35	18	2415
Truckee RS	Nevada	16	39.29	120 11	5995	90	58	87	57	82	55	40	-10	8230
Tujunga	Los Angeles	9	34.29		1820	103	70	99	69	94	67	36	20	
Tulare	Tulare	13	36.20		290	105	72	101	71	96	69	39	24	
Tulelake	Siskiyou	16	42		4035	92	60	88	59	83	57	41	-5	6854
Turlock	Stanislaus	12	37.5		100	104	72	100	70	95	68	40	24	
Turntable Creek	Plumas	0	40.79		1067	105	69	101	68	95	66	28	24	
Tustin Irvine Rch	Orange	8	33.70	117 47	118	99	71	92	69	85	68	27	28	1856

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range	Winter Minimum	HDD
Twentynine Palms	San Bernardino	0	34.09	116 03	1975	110	71	107	70	103	69	31	21	1973
Twin Lakes	Mono	16	38.70		7829	73	49	64	47	57	46	30	-7	9196
Twitchell Dam	San Luis	5	35		582	99	70	93	68	88	66	26	26	
UCLA	Los Angeles	9	34.09		430	93	69	86	68	80	66	20	39	1509
Ukiah	Mendocino	2	39.20	123 12	623	100	70	97	69	92	68	42	22	2958
Union City	Alameda	3	37.6		5	90	67	87	66	81	63	20	25	
Upland	San Bernardino	10	34.1		1605	102	69	98	68	92	66	31	29	2175
Upper Lake RS	Lake	2	39.20	122 57	1347	98	68	95	67	91	64	39	18	
Upper San Leandro	Alameda	3	37.79		394	93	67	87	66	80	63	22	28	
Vacaville	Solano	12	38.40		105	103	71	100	70	94	68	40	23	2788
Valinda	Los Angeles	9	34		340	102	70	98	69	92	68	28	31	
Vallejo	Solano	3	38.09		85	93	67	90	66	84	64	23	28	
Valyermo RS	Los Angeles	14	34.5		3600	100	67	96	66	91	65	41	12	3870
Vandenburg AFB	Santa Barbara	5	34.70	122 48	368	85	62	77	61	71	60	16	30	3451
Ventura	Ventura	6	34.29		341	89	68	82	67	76	66	15	29	
Victorville Pumps	San Bernardino	14	34.5		2858	105	67	101	65	97	62	39	14	3191
View Park	Los Angeles	6, 8	34		300	95	69	88	68	78	66	18	36	
Visalia	Tulare	13	36.29		325	103	71	100	70	96	69	38	25	2459
Vista	San Diego	7	33.20		510	96	69	90	68	85	67	16	30	
Volta PH	Merced	12	40.5		2220	101	66	98	65	93	63	33	21	
Walnut	Los Angeles	9	34		550	101	70	97	69	92	69	30	28	
Walnut Creek	Contra Costa	12	37.90		245	100	69	94	67	87	66	32	23	
Walnut Grove	Sacramento	12	38.20		23	102	70	98	69	92	68	37	24	
Warner Springs	San Diego	14	33.29		3180	100	67	95	66	91	65	40	15	3591
Wasco	Kern	13	35.59		333	105	71	101	70	97	68	36	23	2466
Watsonville	Santa Cruz	3	36.90		95	86	66	82	64	79	61	22	28	3418
Weaverville RS	Trinity	16	40.70		2050	100	67	95	66	89	63	46	10	4992
Weed FD	Siskiyou	16	41.40		3590	92	63	89	62	84	59	35	4	
West Carson	Los Angeles	9	33.79		100	92	69	87	68	81	66	18	32	
West Covina	Los Angeles	9	34		365	102	70	98	69	92	68	34	29	
West Hollywood	Los Angeles	9	34		290	95	70	89	69	82	67	20	38	
West Puente Valley			34		250	101	70	97	69	91	68	26	31	
Westminster	Orange	6	33.79		38	95	70	88	68	81	67	23	33	
Whiskeytown Res	Shasta	11	40.59		1295	105	69	101	68	96	67	31	25	
White Mtn 1	Mono	16	37.5		10150	73	49	69	47	65	45	37	-15	
White Mtn 2	Mono	16	37.59		12470	61	42	58	41	54	40	38	-20	
Whittier	Los Angeles	9	34		320	99	69	90	68	84	67	24	31	
Wildrose RS	Inyo	16	36.29		4100	100	64	97	63	93	61	33	13	
Williams	Colusa	11	39.20		85	104	71	100	70	94	68	36	24	
Willits	Mendocino	2	39.40	123 19	1350	95	66	89	65	82	62	38	18	
Willow Brook	Los Angeles	8	33.90		60	97	70	90	69	83	67	21	35	
Willow Creek	Humboldt	2	41	123 38	461	104	70	98	68	92	66	35	22	
Willows	Colusa	11	39.5		140	104	71	100	70	94	68	36	22	2836
Winters	Yolo	12	38.5		135	104	71	99	70	93	68	38	24	2593
Woodfords	Alpine	16	38.79		5671	92	59	89	58	84	56	32	0	6047
Woodland	Yolo	12	38.70		69	106	72	101	71	96	69	40	25	2708
Woodside	San Mateo	3	37.5		75	92	67	84	66	76	63	24	22	
Yorba Linda	Orange	8	33.90		350	102	70	94	69	88	68	31	30	1643
Yosemite Park Hq	Mariposa	16	37.70		3970	97	63	94	62	90	60	38	11	4785

City	County	Climate Zone	Latitude	Longitude (Degree Minute)	Elevation	Summer .1% Dry Bulb	.1% Wet Bulb	.5% Dry Bulb	.5% Wet Bulb	2% Dry Bulb	2% Wet Bulb	Range	Winter Minimum	HDD
Yreka	Siskiyou	16	41.70		2625	99	66	95	65	90	64	39	8	5395
Yuba City	Sutter	11	39.09		70	105	69	101	69	96	68	36	24	
Yucaipa	San Bernardino	10	34		2600	106	68	102	67	98	65	35	27	

D: Indoor Air Quality

EXECUTIVE SUMMARY

Public Resources Code (PRC), Section 25402, requires the California Energy Commission (Commission) to develop, implement, and periodically update energy efficiency standards for new buildings. AB 4655 (Tanner, 1988) added PRC Section 25402.8, requiring the Commission to examine the effects of energy efficiency standards on indoor air quality. Specifically, this legislation requires the Commission to: a) include in its deliberations, while developing building standards, the impact these standards could have on indoor air quality; and b) to complete, by December 31, 1991, a review of current energy efficiency standards to determine whether modifications are needed to reduce the potential for indoor air pollution. This report is a summary of that review.

History of Concern over Indoor Air Quality

Combined, the following factors have raised concern over the impact of indoor pollutants on human health:

The discovery that high concentrations of the carcinogenic (cancer-causing) radon gas may be found in more homes than previously assumed

Discovery of the possibility of high levels of carcinogenic asbestos fibers in some buildings with past applications of asbestos, a widely used insulating material

Growing number of non-specific health symptoms, which tend to occur when exposed to indoor pollutants

Employment trends toward working indoors

Building industry trends toward controlled indoor environments without occupant access to system controls or operable windows

Building industry practices during the energy crisis of restricting, if not eliminating, the use of outside air in heating and cooling systems

Building energy standards' incorporation of infiltration control requirements to reduce uncontrolled building air leakage

The growing number of volatile organic compounds found in typical homes and offices because of the use of manufactured products

Summary of Knowledge About Indoor Air Pollutants, Health Effects, Tight Building Syndrome and Building Related Illness

The main classes of pollutants (described along with related health effects) are:

- Biological contaminants
- Radon
- Combustion products
- Particulate matter
- Volatile organic compounds (VOCs) and semi-volatile organic compounds (SOCs)

"Tight building syndrome" cannot be linked to specific exposure to specific pollutants; a building-related illness (such as Legionnaire's Disease) can. Multiple chemical sensitivity (MCS), also known as Environmental Illness (EI), affects a significant subset of the population, leading to a heightened chemical sensitivity well beyond the normal sensitivity of the rest of the population.

Conceptual Approaches to Regulating Environmental Pollutants and Their Applicability to Indoor Environments

Environmental pollutants are currently regulated according to their potential to cause cancer or health effects other than cancer. This potential is assessed through the health risk assessment process. However, this risk assessment process is not useful for establishing energy-conserving ventilation requirements for buildings since there is no numerical correlation between ventilation rates and specific levels at risk.

The main factors that will affect the concentration of indoor air pollutants include:

- Effectiveness of any ventilation system in removing pollutants
- Care and maintenance of a building and its related systems
- Behavior of the building occupants
- Existence of entry pathways for pollutants
- Overall "air tightness" of the building
- Existence of significant indoor sources of pollution

Technological Approaches To Reducing Indoor Pollutants

The California Department of Health Services and Air Resources Board has identified source elimination as the most effective, economical and reliable method for reducing indoor concentrations of pollutants, with ventilation necessary for further reducing residual indoor pollutant levels. Ventilation is sometimes the most practical solution to immediate indoor air quality problems involving specific indoor pollutants from identifiable sources. In general, maintaining acceptable indoor air quality involves the approach of eliminating all known sources and providing adequate ventilation.

The concentration of a pollutant in a space is a function of the source strength and the dilution rate. The effects of the dilution rate on source strength is not easily quantifiable and is generally considered to be variable making it impossible to establish specific ventilation rates appropriate to all situations.

When formulating ventilation requirements for the purposes of reducing potential for pollutant accumulation, it is difficult to establish any one pollutant as an indicator of the absence of pollution-related health effects. Carbon dioxide levels have been identified from experience and limited studies as a roughly reliable indicator of acceptable indoor air quality. Total volatile organic compound (TVOC) concentration has been applied with some limited success as a general indicator of indoor pollutant levels. No other pollutants have been identified so far as capable of such an indicator role.

ASHRAE Standard 62-1989 bases its minimum ventilation rate on the same principle of minimizing levels of carbon dioxide as a way of maintaining indoor pollution within acceptable levels, as well as a general belief that higher levels of dilution reduce the potential for adverse health effects of indoor air pollution. The other components of the standard are based on committee consensus. Scientists have attempted to establish health-protective ventilation rates by using pollutants other than carbon dioxide as a surrogate for pollutant levels, but direct relationships between pollutant concentration and ventilation rates are difficult to establish because of the many factors that can affect the concentration of pollutants in any indoor environment.

The removal of pollutants from space can be accomplished in two ways: the pollutant-laden air can be exhausted from the space or treated to remove the pollutants of concern. At present, only limited confidence can be placed in the effectiveness of air treatment systems for protecting against health effects of indoor pollution due to the following factors: 1) air treatment is presently possible for only a small group of indoor pollutants; 2) the safe levels of many of these pollutants have not been established.

California's Energy Efficiency Standards

The Commission is required to develop cost-effective energy efficiency standards that include both mandatory and performance requirements. CEQA specifically requires the Commission to identify any potential negative environmental effects of compliance with these standards and to present alternatives, which will mitigate these effects.

The efficiency standards have unique features that conceivably could lead to increased indoor concentrations of pollutants. These include infiltration control requirements and mandatory insulation levels. There are no specific requirements for mechanical ventilation of residential buildings. The Commission concludes that these requirements do not present a major risk of increased indoor pollutants and that residential buildings are adequately ventilated because of the universal application of operable windows.

The standards for nonresidential buildings have incorporated minimum ventilation requirements since their effective date in 1978. Two revisions of the standards reflect the following facts:

Revision of ASHRAE Standard 62 in 1981 and 1989

Further research pointing to the need for at least 15-cfm per person to ensure that the concentrations of pollutants do not pose a risk of significant health effects

The inappropriateness of distinguishing between smoking and non-smoking buildings given the large number of hazardous indoor pollutants

Conclusion that demand controlled ventilation based on the levels of an acceptable indicator pollutant is the only reliable performance-based ventilation method

The 1992 nonresidential ventilation requirements can be met through natural or mechanical ventilation. The natural ventilation provisions limit this option to certain building geometrics. The mechanical ventilation requirements establish a minimum ventilation rate as the larger of a table value, in cfs per square foot, or 15 cfs per person. For office buildings, 0.15 cfs per square foot is required. This means that when an occupant density of 100 square feet per occupant is exceeded, the ventilation rate will be 15 cfs per person to reflect the increased need for carbon dioxide dilution.

The standards include provisions or requirements for the following:

Demand controlled ventilation

Supply of ventilation on a whole building basis

Pre-occupancy purge requirements

System control requirements

Requirements for supply of air to zonal heat pumps and fan coils

Completion and balancing requirements

The combined effects of higher ventilation rates and better efficiency requirements resulted in statewide energy savings. The Commission concluded the compliance with nonresidential standards would not lead to a significant increase in outdoor air pollution.

Commission's Strategy for Future Indoor Air Quality Research and Standards Development

Examination of the literature on indoor air quality issues shows substantial uncertainty about not only the best mechanisms for mitigating the problem in buildings, but also the essential elements of the problem being addressed in each situation. The Commission will continue examining these issues as part of the long-term plan to assess and update its building efficiency standards, as resources become available.

Based on the following key factors, the Commission is best equipped to establish ventilation rates for buildings covered by the energy efficiency standards.

The need for ventilation, and the extent of ventilation, should be determined from knowledge of the state's energy needs, as well as the magnitude of the indoor pollution problem.

Ventilation is not aimed at concentrations of single pollutants but at removing whole classes of pollutants.

The existing health risk assessment process is of limited usefulness in formulating specific numerical requirements for ventilation.

The Commission, since the first standards were established in 1978, has considered the impacts of its standards on indoor air quality in all of its revisions.

The Commission is the only agency assigned the task of balancing the impacts of its standards on both indoor and outdoor environments.

The Commission is able to assess the technological achievability, and cost effectiveness of its energy conservation standards.

The Commission's work to date includes:

Air leakage tests on pilot samples of homes built before and after the standards took effect.

Investigation of potential building elements that can effect indoor air quality and ventilation rates.

Participation of the Interagency Work Group on Indoor Air Quality, chaired by the Department of Health Services.

Revision of the minimum ventilation requirements for nonresidential buildings to reflect the latest understanding of the nature of pollution-related health effects.

Analysis of the potential impacts of compliance with the Commission's standards.

In complying with the statutory requirements of the Warren-Alquist Act, the Commission conducted an assessment of its building standards and indoor air quality during its 1992 revisions to the standards. The Commission concluded that the combined effects of occupant behavior, emission from pollutant sources and HVAC design necessitated substantial revisions to the nonresidential ventilation requirements. The Commission chose not to develop mechanical ventilation requirements for single family homes due to universal use of operable windows in homes.

Future work of the Commission, assuming availability of resources, will include:

Continued investigation and monitoring of both residential and nonresidential building air exchange rates.

Coordination with DHS, ARB, and federal agencies to develop a more reliable health risk assessment process for addressing indoor pollution problems.

Research in cooperation with ARB and DHS of the effectiveness of interim pollution reduction measures such as building commissioning and bake-outs.

Further research of ventilation effectiveness in terms of air mixing and the ability to remove the pollutants of most concern.

Continued standards refinement and public education efforts to help building occupants understand the factors affecting indoor air quality.

For detailed information, please request the following staff report from the Commission:

“California’s Energy Efficiency Standards and Indoor Air Quality”

E: Certified Computer Programs

Call the Energy Hotline for the latest update at 916/654-5106 or
1-800/772-3300 (in California only)

F: Publications Directory

Call the Energy Hotline for the latest update at 916/654-5106 or 1-800/772-3300 (in California only)

G: Glossary

ACCA
is the Air-Conditioning Contractors of America.

ACCESSIBLE
is having access thereto, but which first may require removal or opening of access panels, doors, or similar obstructions.

ADDITION
is any change to a building that increases conditioned floor area and conditioned volume. See also, NEWLY CONDITIONED SPACE.

AIR-TO-AIR HEAT EXCHANGER
is a device which will reduce the heat losses or gains which occur when a building is mechanically ventilated, by transferring heat between the conditioned air being exhausted and the unconditioned air being supplied.

ALTERATION
is any change to a building's water heating system, space conditioning system, lighting system, or envelope that is not an addition.

ALTERNATIVE CALCULATION METHODS (ACMs)
are the Commission's Public Domain Computer Programs, one of the Commission's Simplified Calculation Methods, or any other calculation method approved by the Commission.

ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE)
is a measure of the percentage of heat from the combustion of gas or oil which is transferred to the space being heated during a year, as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112.

ANNUNCIATED
is a visual signaling device that indicates the on, off, or other status of a load.

ANSI
is the American National Standards Institute.

APPLIANCE EFFICIENCY REGULATIONS
are the regulations in Title 20, Sections 1601 et. seq. of the California Code of Regulations.

APPROVED BY THE COMMISSION
means approval under Section 25402.1 of the Public Resources Code.

APPROVED CALCULATION METHOD
(See ALTERNATIVE CALCULATION METHODS).

ARI
is the Air-conditioning and Refrigeration Institute.

ASHRAE
is the American Society of Heating, Refrigerating, and Air-conditioning Engineers.

ASME
is the American Society of Mechanical Engineers.

ASTM
is the American Society for Testing and Materials.

ATRIUM
is an opening through two or more floor levels other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning, or other equipment which is enclosed space and not defined as a mall.

AUDITORIUM
is the part of a public building where an audience sits in fixed seating, or a room, area, or building with fixed seats used for public meetings or gatherings not specifically for the viewing of dramatic performances.

AUTO REPAIR
is the portion of a building used to repair automotive equipment and/or vehicles, exchange parts, and may include work using an open flame or welding equipment.

AUTOMATIC
is capable of operating without human intervention.

AUTOMATIC TIME SWITCH CONTROL DEVICES
are devices capable of automatically turning loads off and on based on time schedules.

BANK/FINANCIAL INSTITUTION
is an area in a public establishment used for conducting financial transactions including the custody, loan, exchange, or issue of money, for the extension of credit, and for facilitating the transmission of funds.

BUILDING
is any structure or space for which a permit is sought.

BUILDING ENVELOPE
is the ensemble of exterior and demising partitions of a building that enclose conditioned space.

CAPTIVE-KEY OVERRIDE
is a type of lighting control in which the key that activates the override cannot be [removed] released when the lights are in the on position.

CERTIFYING ORGANIZATION
is an independent organization recognized by the Commission to certify manufactured devices for performance values in accordance with procedures adopted by the Commission.

CHANDELIERS
(see ORNAMENTAL CHANDELIERS).

CHAPTER 1
means the California Code of Regulations, Title 24, Part 2, Chapter 1.

CLASSROOM, LECTURE, OR TRAINING
is a room or area where an audience or class receives instruction.

CLIMATE CONTROL SYSTEM
(See SPACE CONDITIONING SYSTEM).

CLIMATE ZONES
are the 16 geographic areas of California for which the Commission has established typical weather data, prescriptive packages and energy budgets. Climate zone boundary descriptions are in the document "California Climate Zone Descriptions (July 1995, incorporated herein by reference)." Figure 1-A is an approximate map of the 16 climate zones.

COEFFICIENT OF PERFORMANCE (COP), COOLING,
is the ratio of the rate of net heat removal to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units, as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112.

COEFFICIENT OF PERFORMANCE (COP), HEATING,
is the ratio of the rate of net heat output to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units, as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112.

COMMERCIAL AND INDUSTRIAL STORAGE
is a room, area, or building used for storing items.

COMMISSION
is the California State Energy Resources Conservation and Development Commission.

COMPLETE BUILDING
is an entire building with one occupancy making up 90 percent of the conditioned floor area (see also ENTIRE BUILDING).

CONDITIONED FLOOR AREA (CFA)
is the floor area (in square feet) of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces of exterior walls enclosing the conditioned space.

CONDITIONED SPACE
is space in a building that is either directly conditioned, indirectly conditioned, or semi-conditioned.

CONDITIONED VOLUME
is the total volume (in cubic feet) of the conditioned space within a building.

CONVENTION, CONFERENCE, MULTIPURPOSE AND MEETING CENTERS
is an assembly room, area, or building that is used for meetings, conventions and multiple purposes including, but not limited to, dramatic performances, and that has neither fixed seating nor fixed staging.

COOLING EQUIPMENT
is equipment used to provide mechanical cooling for a room or rooms in a building.

CORRIDOR
is a passageway or route into which compartments or rooms open.

COVERED PRODUCT

is an appliance regulated by the efficiency standards established under the National Appliance Energy Conservation Act, 42 U.S.C. Section 6291 et seq.

CRAWL SPACE

is a space immediately under the first floor of a building adjacent to grade.

CTI

is the Cooling Tower Institute.

C-VALUE (also known as C-FACTOR)

is the time rate of heat flow through unit area of a body induced by a unit temperature difference between the body surfaces, in Btu (hr. x ft.^{2} x ^{o}F). It is not the same as K-value or K-factor.

DAYLIT AREA

is the space on the floor that is the larger of (a) plus (b), or (c);

(a) For areas daylit by vertical glazing, the daylit area has a length of 15 feet, or the distance on the floor, perpendicular to the glazing, to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side, the distance to an opaque partition, or one-half the distance to the closest skylight or vertical glazing, whichever is least.

(b) For areas daylit by horizontal glazing, the daylit area is the footprint of the skylight plus, in each of the lateral and longitudinal dimensions of the skylight, the lesser of the floor-to-ceiling height, the distance to the nearest 60-inch or higher opaque partition, or one-half the horizontal distance to the edge of the closest skylight or vertical glazing.

(c) The daylit area calculated using a method approved by the Commission.

DECORATIVE GAS APPLIANCE

is a gas appliance that is designed or installed for visual effect only, cannot burn solid wood, and simulates a fire in a fireplace.

DEGREE DAY, HEATING

is a unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal annual heating load of a building. For any one day, when the mean temperature is less than 65^{o}F, there exist as many degree days as there are Fahrenheit degrees difference in temperature between the mean temperature for the day and 65^{o}F. The number of degree days for specific geographical locations are those listed in the Residential Manual. For those localities not listed in the Residential Manual the number of degree days is as determined by the applicable enforcing agency.

DEMISING PARTITIONS

are barriers that separate conditioned space from enclosed unconditioned space.

DEMISING WALL

is a wall that is a demising partition.

DESIGN CONDITIONS

are the parameters and conditions used to determine the performance requirements of space conditioning systems. Design conditions for determining design heating and cooling loads are specified in Section 144(b) for nonresidential, high-rise residential, and hotel/motel buildings and in Section 150(h) for low-rise residential buildings.

DESIGN HEAT GAIN RATE

is the total calculated heat gain through the building envelope under design conditions.

DESIGN HEAT LOSS RATE

is the total calculated heat loss through the building envelope under design conditions.

DINING

is a room or rooms in a restaurant or hotel/motel (other than guest rooms) where meals that are served to the customers will be consumed.

DIRECTLY CONDITIONED SPACE

is an enclosed space that is provided with wood heating, is provided with mechanical heating that has a capacity exceeding 10 Btu/(hr ft^2), or is provided with mechanical cooling that has a capacity exceeding 5 Btu/(hr ft^2, unless the space conditioning system is designed and thermostatically controlled to maintain a process environment temperature less than 55 F or to maintain a process environment temperature greater than 90 F for the whole space that the system serves, or unless the space conditioning system is designed and controlled to be incapable of operating at temperatures above 55 F or incapable of operating at temperatures below 90 F at design conditions.

DISPLAY LIGHTING

is lighting confined to the area of a display that provides a higher level of illuminance than the level of surrounding ambient illuminance.

DISPLAY PERIMETER

is the length of an exterior wall in a B, F-1 or M occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk.

DISPLAY, PUBLIC AREA

are areas for the display of artwork, theme displays, and architectural surfaces in dining and other areas of public access, excluding restrooms and separate banquet rooms.

DISPLAY, SALES FEATURE

is an item or items that requires special highlighting to visually attract attention and that is visually set apart from the surrounding area.

DISPLAY, SALES FEATURE FLOOR

is a feature display in a retail store, wholesale store, or showroom that requires display lighting.

DISPLAY, SALES FEATURE WALL

are the wall display areas, in a retail or wholesale space, that are in the vertical plane of permanent walls or partitions, and that are open shelving feature displays or faces of internally illuminated transparent feature display cases within the Gross Sales Wall Area.

DUAL-GLAZED GREENHOUSE WINDOWS

are a type of dual-glazed fenestration product which adds conditioned volume but not conditioned floor area to a building.

EAST-FACING

is oriented to within 45 degrees of true east, including $45^{o}00'00''$ south of east (SE), but excluding $45^{o}00'00''$ north of east (NE).

ECONOMIZER, AIR

is a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical cooling.

ECONOMIZER, WATER

is a system by which the supply air of a cooling system is cooled directly or indirectly by evaporation of water, or other appropriate fluid, in order to reduce or eliminate the need for mechanical cooling.

EFFECTIVE APERTURE (EA)

is (1) for windows, the visible light transmittance (VLT) times the window wall ratio; and (2) for skylights, the well index times the VLT times the skylight area times 0.85 divided by the gross exterior roof area.

EFFICACY

is the ratio of light from a lamp to the electrical power consumed (including ballast losses), expressed in lumens per watt.

ELECTRICAL/MECHANICAL ROOM

is a room in which the building's electrical switchbox or control panels, and/or HVAC controls or equipment is located.

ENCLOSED SPACE

is space that is substantially surrounded by solid surfaces.

ENERGY BUDGET

is the maximum amount of source energy that a proposed building, or portion of a building, can be designed to consume, calculated with the approved procedures specified in Part 6.

ENERGY EFFICIENCY RATIO (EER)

is the ratio of net cooling capacity (in Btu/hr) to total rate of electrical energy (in watts), of a cooling system under designated operating conditions, as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112.

ENERGY FACTOR (EF)

is the ratio of energy output to energy consumption of a water heater, expressed in equivalent units, under designated operating conditions over a 24-hour use cycle, as determined using the applicable test method in the Appliance Efficiency Regulations.

ENERGY OBTAINED FROM DEPLETABLE SOURCES

is electricity purchased from a public utility, or any energy obtained from coal, oil, natural gas, or liquefied petroleum gases.

ENERGY OBTAINED FROM NONDEPLETABLE SOURCES

is energy that is not energy obtained from depletable sources.

ENFORCING AGENCY

is the city, county, or state agency responsible for issuing a building permit.

ENTIRE BUILDING

is the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all existing conditioned and unconditioned space within the structure.

ENVELOPE means BUILDING ENVELOPE.

EXERCISE CENTER/GYMNASIUM

is a room or building equipped for gymnastics, exercise equipment, or indoor athletic activities.

EXFILTRATION

is uncontrolled outward air leakage from inside a building, including leakage through cracks and interstices, around windows and doors, and through any other exterior partition or duct penetration.

EXHIBIT

is a room or area that is used for exhibitions that has neither fixed seating nor fixed staging.

EXPOSED THERMAL MASS

is mass that is directly exposed (uncovered) to the conditioned space of the building.

EXTERIOR DOOR

is a door through an exterior partition that is opaque or has a glazed area that is less than or equal to one-half of the door area. Doors with a glazed area of more than one-half of the door area are treated as a fenestration product.

EXTERIOR FLOOR/SOFFIT

is a horizontal exterior partition, or a horizontal demising partition, under conditioned space. For low-rise residential occupancies, exterior floors also include those on grade.

EXTERIOR PARTITION

is an opaque, translucent, or transparent solid barrier that separates conditioned space from ambient air or space that is not enclosed. For low-rise residential occupancies, exterior partitions also include barriers that separate conditioned space from unconditioned space, or the ground.

EXTERIOR ROOF/CEILING

is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below, and that is not an exterior door or skylight.

EXTERIOR ROOF/CEILING AREA

is the area of the exterior surface of exterior roof/ceilings.

EXTERIOR WALL

is any wall or element of a wall, or any member or group of members, which defines the exterior boundaries or courts of a building and which has a slope of 60 degrees or greater with the horizontal plane. An exterior wall or partition is not an exterior floor/soffit, exterior door, exterior roof/ceiling, window, skylight, or demising wall.

EXTERIOR WALL AREA

is the area of the opaque exterior surface of exterior walls.

FENESTRATION PRODUCT

is any transparent or translucent material plus any sash, frame, mullions, and dividers, in the envelope of a building, including, but not limited to: windows, sliding glass doors, french doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one-half of the door area.

FIELD-FABRICATED FENESTRATION PRODUCT OR EXTERIOR DOOR

is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits and curtainwalls).

FIREPLACE

is a hearth and firechamber or similar prepared place in which a solid fuel fire may be burned, as defined in UBC Section 3702 and as further clarified in UBC Section 3707; these include but are not limited to factory-built fireplaces, masonry fireplaces, and masonry heaters.

FLOOR/SOFFIT TYPE

is a floor/soffit assembly having a specific heat capacity, framing type, and U-value.

FRAMED PARTITION or ASSEMBLY

is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.

GAS HEATING SYSTEM

is a natural gas or liquified petroleum gas heating system.

GAS LOG

is a self-contained, free-standing, open-flame, gas-burning appliance consisting of a metal frame or base supporting simulated logs, and designed for installation only in a vented fireplace.

GENERAL COMMERCIAL AND INDUSTRIAL WORK

is a room, area, or building in which an art, craft, assembly or manufacturing operation is performed.

GENERAL LIGHTING

is lighting designed to provide a substantially uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect. When designed for lower-than-task illuminance used in conjunction with other specific task lighting systems, it is also called “ambient” lighting.

GLAZING

(See FENESTRATION PRODUCT).

Center of Glass U-value:

The U-value of an IG unit (or single glazing) other than within two and a half inches of dividers or edge of glass.

Dividers:

Muntins; wood, aluminum or vinyl glazing dividers; may be true divided lights, between the panes, or applied to the exterior or interior of the glazing.

Edge of Glass:

The area of glazing within two and a half inches of the spacer.

Frame Types:

- **Thermal Break**

  Metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl, with a lower conductivity.

- **Vinyl**

  A PVC compound used for frame and mountain elements, with a lower conductivity than metal and a similar conductivity to wood.

- **Gap Width**

  The distance between glazings in multi-glazed systems. This is typically measured from inside surface to inside surface, though some manufacturers may report “overall” IG width which is measured from outside surface to outside surface.

- **Gas Infills**

  Air, argon, krypton, CO_2, SF_6, or a mixture of these gasses. Gas infills are between the panes of dual or triple glazing.

- **Grilles**

  see Dividers

- **IG Unit**

  Insulating glass unit; includes the glazings, spacer(s), films (if any), gas infills, and edge caulking.

- **Low-e Coatings**

  Low emissivity metallic coatings

- **Soft Coat**
  "Sputter" applied coating; sprayed on at a high temperature; usually susceptible to degradation (oxidation) from contact through handling or storing; generally provides a lower emissivity (and better thermal performance) than hard coatings.
- **Hard Coat**
  Low emissivity metallic coatings applied pyrolytically (at or near the melting point of the glass so that it bonds with the surface layer of glass); hard coatings are not subject to oxidation and scratching as the soft coats are. The first generation of hard coatings performed only about one fourth as well as the soft coats (emissivities around 0.40 as compared to emissivities around 0.10), but new hard coat technologies provide performance very close to that of the soft coatings.

  Note: Low-e coatings will lower the shading coefficient in addition to reducing heat loss, but there is no direct relationship between emissivity and shading coefficient (e.g., a dual glazed unit with an emissivity of 0.22 may have a shading coefficient of 0.86 - nearly identical to clear dual glazing - or it may have a shading coefficient of 0.40).
- **Mullion**
  Vertical framing members separating adjoining window or door sections.
- **Muntins**
  see Dividers
- **NFRC**
  National Fenestration Rating Council. This is a national organization of fenestration product manufacturers, glazing manufacturers, manufacturers of related materials, utilities, state energy offices, laboratories, home builders, specifiers (architects), and public interest groups.

Spacers:

- **Aluminum**
  Metal channel that is used either against the glass (sealed along the outside edge of the insulated glass unit), or separated from the glass by one or more beads of caulk.
- **Squiggle**
  A flexible material, usually butyl, formed around a thin corrugated aluminum strip
- **"Insulating"**
  Non-metallic, fairly non-conductive materials, usually of rubber compounds
- **Others**
  Wood, fiberglass, composites

Suspended Films:

Low-e coated plastic films stretched between the elements of the spacers between panes of glazing; acts as a reflector to slow the loss of heat from the interior to the exterior.

GOVERNMENTAL AGENCY

is any public agency or subdivision thereof, including, but not limited to, any agency of the state, a county, a city, a district, an association of governments, or a joint power agency.

GROCERY STORE

is a room, area, or building that has as its primary purpose the sale of foodstuffs requiring additional preparation prior to consumption.

GROSS EXTERIOR ROOF AREA

is the sum of the skylight area and the exterior roof/ceiling area.

GROSS EXTERIOR WALL AREA

is the sum of the window area, door area, and exterior wall area.

GROSS SALES FLOOR AREA

is the total area (in square feet) of retail store floor space that is (1) used for the display and sale of merchandise; or (2) associated with that function, including, but not limited to, sales transactions areas, fitting rooms, and circulation areas and entry areas within the space used for display and sale.

GROSS SALES WALL AREA

is the area (in square feet) of the inside of exterior walls and permanent full height interior partitions within the gross sales floor area of a retail store that is used for the presentation of merchandise for sale, less the area of openings, doors, windows, baseboards, wainscots, mechanical or structural elements, and other obstructions preventing the use of the area for the presentation of merchandise.

HABITABLE STORY

is a story that contains space in which humans may work or live in reasonable comfort, and that has at least 50 percent of its volume above grade.

HEAT CAPACITY (HC)

of an assembly is the amount of heat necessary to raise the temperature of all the components of a unit area in the assembly one degree F. It is calculated as the sum of the average thickness times the density times the specific heat for each component, and is expressed in Btu per square foot per degree F.

HEAT PUMP

is a device that is capable of heating by refrigeration, and that may include a capability for cooling.

HEATING EQUIPMENT

is equipment used to provide mechanical heating for a room or rooms in a building.

HEATING SEASONAL PERFORMANCE FACTOR (HSPF)

is the total heating output of a heat pump (in British thermal units) during its normal use period for heating divided by the total electrical energy input (in watt-hours) during the same period, as determined using the applicable test method in the Appliance Efficiency Regulations.

HI

is the Hydronics Institute.

HIGH BAY

is a space with luminaires 25 feet or more above the floor.

HIGH-RISE RESIDENTIAL BUILDING
is a building, other than a hotel/motel, of occupancy group R-1 with four or more habitable stories.

HORIZONTAL GLAZING
(See SKYLIGHT).

HOTEL FUNCTION AREA
is a hotel room or area such as a hotel ballroom, meeting room, exhibit hall, or conference room, together with prefunction areas and other spaces ancillary to its function.

HOTEL LOBBY
is the contiguous spaces in a hotel/motel between the main entrance and the front desk, including waiting and seating areas, and other spaces encompassing the activities normal to a hotel lobby function.

HOTEL/MOTEL
is a building or buildings incorporating six or more guest rooms or a lobby serving six or more guest rooms, where the guest rooms are intended or designed to be used, or which are used, rented, or hired out to be occupied, or which are occupied for sleeping purposes by guests, and all conditioned spaces within the same building envelope. Hotel/motel also includes all conditioned spaces which are (1) on the same property as the hotel/motel, (2) served by the same central HVAC system as the hotel/motel, and (3) integrally related to the functioning of the hotel/motel as such, including, but not limited to, exhibition facilities, meeting and conference facilities, food service facilities, lobbies, and laundries.

HVAC SYSTEM
(see SPACE CONDITIONING SYSTEM).

INDIRECTLY CONDITIONED SPACE
is enclosed space including, but not limited to, unconditioned volume in atria, that (1) is not directly conditioned space; and (2) either (a) has an area-weighted heat transfer coefficient to directly conditioned space exceeding that to the outdoors or to unconditioned space, or (b) is a space through which air from directly conditioned spaces is transferred at a rate exceeding 3 air changes per hour.

INFILTRATION
is uncontrolled inward air leakage from outside a building, or unconditioned space, including leakage through cracks and interstices, around windows and doors, and through any other exterior or demising partition or pipe or duct penetration.

INTEGRATED PART LOAD VALUE (IPLV)
is a single number figure of merit based on part load EER or COP expressing part load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment as determined using the applicable test method in the Appliance Efficiency Regulations or Section 112.

ISOLATION DEVICE
is a device that prevents the conditioning of a zone or group of zones in a building while other zones of the building are being conditioned.

KITCHEN/FOOD PREPARATION
is a room or area with cooking facilities and/or an area where food is prepared.

LAUNDRY
is a place where laundering activities occur.

LIBRARY
is a repository for literary materials, such as books, periodicals, newspapers, pamphlets and prints, kept for reading or reference.

LOCKER/DRESSING ROOM
is a room or area for changing clothing, sometimes equipped with lockers.

LOUNGE/RECREATION
is a room used for leisure activities which may be associated with a restaurant or bar.

LOW BAY
is a space with luminaires less than 25 feet above the floor.

LOW-RISE RESIDENTIAL BUILDING
is a building, other than a hotel/motel, that is of occupancy group R-1 and is three stories or less, or that is of occupancy group R-3.

LPG
is Liquified Petroleum Gas.

LUMEN MAINTENANCE DEVICE
is a device capable of automatically adjusting the light output of a lighting system throughout a continuous range to provide a preset level of illumination.

LUMINAIRE
is a complete lighting unit consisting of a lamp and the parts designed to distribute the light, to position and protect the lamp, and to connect the lamp to the power supply; commonly referred to as "lighting fixtures" or "instruments."

MAIN ENTRY LOBBY/RECEPTION/WAITING
is the lobby of a building that is directly located by the main entrance of the building and includes the reception area, sitting areas, and public areas.

MALLS, ARCADES AND ATRIA
is a public passageway or concourse that provides access to rows of stores or shops.

MANUAL
is capable of being operated by personal intervention.

MANUFACTURED DEVICE
is any heating, cooling, ventilation, lighting, water heating, refrigeration, cooking, plumbing fitting, insulation, door, fenestration product, or any other appliance, device, equipment, or system subject to Sections 110 through 119 of Part 6.

MANUFACTURED FENESTRATION PRODUCT
is a fenestration product typically assembled before delivery to a job site. Knocked down or partially assembled products sold as a fenestration product must be considered a manufactured fenestration product and meet the rating and labeling requirements for manufactured fenestration products.

MECHANICAL COOLING

is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space. In nonresidential, high-rise residential, and hotel/motel buildings cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling.

MECHANICAL HEATING

is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy from depletable sources to directly condition the space.

MEDICAL AND CLINICAL CARE

is a room, area, or building that does not provide overnight patient care and that is used to promote the condition of being sound in body or mind through medical, dental, or psychological examination and treatment, including, but not limited to, laboratories and treatment facilities.

MODELING ASSUMPTIONS

are the conditions (such as weather conditions, thermostat settings and schedules, internal gain schedules, etc.) that are used for calculating a building's annual energy consumption and that are in the Alternative Calculation Methods Manuals.

MOVABLE SHADING DEVICE

(See OPERABLE SHADING DEVICE).

MULTI-SCENE DIMMING SYSTEM

is a lighting control device that has the capability of setting light levels throughout a continuous range, and that has pre-established settings within the range.

MUSEUM

is a space in which works of artistic, historical, or scientific value are cared for and exhibited.

NEWLY CONDITIONED SPACE

is any space being converted from unconditioned to directly conditioned or indirectly conditioned space, or any space being converted from semi-conditioned to directly conditioned or indirectly conditioned space. Newly conditioned space must comply with the requirements for an addition. See Section 149 for nonresidential occupancies and Section 152 for residential occupancies.

NONRESIDENTIAL BUILDING

is any building which is of occupancy group A, B, E, F, H, M or S.
NOTE: Requirements for high-rise residential buildings and hotels/motels are included in the nonresidential sections of Part 6.

NONRESIDENTIAL MANUAL

is the manual developed by the Commission, under Section 25402.1(c) of the Public Resources Code, to aid designers, builders and contractors in meeting the energy efficiency requirements for nonresidential, high-rise residential, and hotel/motel buildings.

NORTH-FACING

is oriented to within 45 degrees of true north, including 45^{o}00’00" east of north (NE), but excluding 45^{o}00’00' west of north (NW).

OCCUPANCY SENSOR, LIGHTING

is a device that automatically turns lights off soon after an area is vacated.

OCCUPANCY TYPE

is one of the following:

- **Auditorium:**
  The part of a public building where an audience sits in fixed seating, or a room, area, or building with fixed seats used for public meetings or gatherings not specifically for the viewing of dramatic performances.

  Auto Repair:
  The portion of a building used to repair automotive equipment and/or vehicles, exchange parts, and may include work using an open flame or welding equipment.
- **Bank/Financial Institution:**
  A public establishment for conducting financial transactions including the custody, loan, exchange, or issue of money, for the extension of credit, and for facilitating the transmission of funds.

  Classroom, Lecture, Or Training:
  A room or area where an audience or classreceives instruction.
- **Commercial and Industrial Storage:**
  A room, area, or building used for storing items.
- **Convention, Conference, or Meeting Center:**
  An assembly room, area, or building that is used for meetings, conventions and multiple purposes including, but not limited to, dramatic performances, and that has neither fixed seating nor fixed staging.
- **Corridor:**
  A passageway or route into which compartments or rooms open.
- **Dining:**
  A room or rooms in a restaurant or hotel/motel (other than guest rooms) where meals that are served to the customers will be consumed.
- **Exhibit:**
  A room or area that is used for exhibitions that has neither fixed seating nor fixed staging.
- **General Commercial and Industrial Work:**
  A room, area, or building in which art, craft, assembly or manufacturing operation is performed.

- **Grocery Store**

  A room, area, or building that has as its primary purpose the sale of foodstuffs requiring additional preparation prior to consumption.
- **Hotel Function Area:**

  A hotel room or area such as a hotel ballroom, meeting room, exhibit hall, or conference room, together with prefunction areas and other spaces ancillary to its function.
- **Hotel Lobby:**

  The contiguous spaces in a hotel/motel between the main entrance and the front desk, including waiting and seating areas, and other spaces encompassing the activities normal to a hotel lobby function.
- **Kitchen:**

  A room or area with cooking facilities in it.
- **Main Entry Lobby:**

  The lobby of a building that is directly located by the main entrance of the building and includes the reception area, sitting areas, and public areas.
- **Malls and Arcades:**

  A public passageway or concourse that provides access to rows of stores or shops.
- **Medical and Clinical Care**:

  A room, area, or building that does not provide overnight patient care and that is used to promote the condition of being sound in body or mind through medical, dental, or psychological examination and treatment, including, but not limited to, laboratories and treatment facilities.
- **Office**:

  A room, area, or building of UBC group B occupancy other than restaurants.
- **Precision Commercial or Industrial Work:**

  A room, area, or building in which an art, craft, assembly or manufacturing operation is performed involving visual tasks of small size or fine detail such as electronic assembly, fine working, metal lathe operations, fine hand painting and finishing, egg processing operations, or tasks of similar visual difficulty.
- **Reception/Waiting Area:**

  An area where customers or clients are greeted prior to conducting business.
- **Religious Worship:**

  A room, area, or building for worship.
- **Restaurant:**

  A room, area, or building that is a food establishment as defined in Section 27520 of the Health and Safety Code.
- **Restroom:**

  A room or suite of rooms providing personal facilities such as toilets and washbasins.
- **Retail and Sales:**

  A room, area, or building in which the primary activity is the sale of merchandise.

- **School:**
  A building or group of buildings that is predominately classrooms and that is used by an organization that provides instruction to students.
- **Stairs, Active/Inactive:**
  A series of steps providing passage from one level of a building to another.

  Support Area:
  A room or area used as a passageway, utility room, storage space, or other type of space associated with or secondary to the function of an occupancy that is listed in these regulations.
- **Support Space:**
  A room or area used as a passageway, utility room, storage space, or other type of space associated with or ancillary to the function of an occupancy that is listed in these regulations.
- **Theater, Motion Picture:**
  An assembly room, hall, or building with tiers of rising seats or steps for the showing of motion pictures.
- **Theater, Performance**:
  An assembly room, hall, or building with tiers of rising seats or steps for the viewing of dramatic performances, lectures, musical events and similar live performances.
- **Vocational Room:**
  A room used to provide training in a special skill to be pursued as a trade.
- **Wholesale Showroom:**
  A room where samples of merchandise are displayed.

OFFICE
is a room, area, or building of UBC group B occupancy other than restaurants.

OPERABLE SHADING DEVICE
is a device at the interior or exterior of a building or integral with a fenestration product, which is capable of being operated, either manually or automatically, to adjust the amount of solar radiation admitted to the interior of the building.

OPTIMAL OVERHANG
is an overhang that completely shades the glazing at solar noon on August 21 and substantially exposes the glass at solar noon on December 21.

ORNAMENTAL CHANDELIERS
are ceiling-mounted, close-to-ceiling, or suspended decorative luminaires that use glass, crystal, ornamental metals, or other decorative material and that typically are used in hotel/motels, restaurants, or churches as a significant element in the interior architecture.

OUTDOOR AIR (Outside air)
is air taken from outdoors and not previously circulated in the building.

OVERALL HEAT GAIN
is the value obtained in Section 143(b)2 for determining compliance with the component envelope approach.

OVERALL HEAT LOSS
is the value obtained in Section 143(b)1 for determining compliance with the component envelope approach.

POOR QUALITY LIGHTING TASKS
are visual tasks that require illuminance category _E_ or greater, because of the choice of a writing or printing method that produces characters that are of small size or lower contrast than good quality alternatives that are regularly used in offices.

PRECISION COMMERCIAL OR INDUSTRIAL WORK
is a room, area, or building in which an art, craft, assembly or manufacturing operation is performed involving visual tasks of small size or fine detail such as electronic assembly, fine woodworking, metal lathe operation, fine hand painting and finishing, egg processing operations, or tasks of similar visual difficulty.

PRIVATE OFFICE or WORK AREA
is an office bounded by 30-inch or higher partitions and is no more than 200 square feet.

PROCESS
is an activity or treatment that is not related to the space conditioning, lighting, service water heating, or ventilating of a building as it relates to human occupancy.

PROCESS LOAD
is a load resulting from a process.

PUBLIC AREAS
are spaces generally open to the public at large, customers, congregation members, or similar spaces, where occupants need to be prevented from controlling lights for safety, security, or business reasons.

PUBLIC FACILITY RESTROOM
is a restroom designed for use by the public.

RAISED FLOOR
is a floor (partition) over a crawl space, or an unconditioned space, or ambient air.

READILY ACCESSIBLE
is capable of being reached quickly for operation, repair, or inspection, without requiring climbing or removing obstacles, or resorting to access equipment.

RECEPTION/WAITING AREA
is an area where customers or clients are greeted prior to conducting business.

RECOOL
is the cooling of air that has been previously heated by space conditioning equipment or systems serving the same building.

RECOVERED ENERGY
is energy used in a building that (1) is mechanically recovered from space conditioning, service water heating, lighting, or process equipment after the energy has performed its original function; (2) provides space conditioning, service water heating, or lighting; and (3) would otherwise be wasted.

REDUCED FLICKER OPERATION
is the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation.

REHEAT
is the heating of air that has been previously cooled by cooling equipment or systems or an economizer.

RELATIVE SOLAR HEAT GAIN
is the ratio of solar heat gain through a fenestration product (corrected for external shading) to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

RELIGIOUS WORSHIP
is a room, area, or building for worship.

REPAIR
is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance.

RESIDENTIAL BUILDING
(See HIGH-RISE RESIDENTIAL BUILDING and LOW-RISE RESIDENTIAL BUILDING).

RESIDENTIAL MANUAL
is the manual developed by the Commission, under Section 25402.1(c) of the Public Resources Code, to aid designers, builders, and contractors in meeting energy efficiency standards for low-rise residential buildings.

RESTAURANT
is a room, area, or building that is a food establishment as defined in Section 27520 of the Health and Safety Code.

RESTROOM
is a room or suite of rooms providing personal facilities such as toilets and washbasins.

RETAIL AND SALES
is a room, area, or building in which the primary activity is the sale of merchandise.

ROOF/CEILING TYPE
is a roof/ceiling assembly having a specific framing type and U-value.

ROOM CAVITY RATIO (RCR) is:

(a) for rectangular rooms $\frac{5H\ (L + W)}{LW}$

;or

(b) for irregular shaped rooms $\frac{2.5\ H \times P}{A}$

Where:

L = Length of room
W = Width of room

H = Vertical distance from the work plane to the center line of the lighting fixture

P = Perimeter of room

A = Area of room

RUNOUT

is piping that is no more than 12 feet long and that is connected to a fixture or an individual terminal unit.

SCHOOL

is a building or group of buildings that is predominately classrooms and that is used by an organization that provides instruction to students.

SCONCE

is a wall mounted decorative light fixture.

SEASONAL ENERGY EFFICIENCY RATIO (SEER)

means the total cooling output of a central air conditioner in British thermal units during its normal usage period for cooling divided by the total electrical energy input in watt-hours during the same period, as determined using the applicable test method in the Appliance Efficiency Regulations.

SEMI-CONDITIONED SPACE

is an enclosed nonresidential space that is provided with wood heating, cooling by direct or indirect evaporation of water, mechanical heating that has a capacity of 10 Btu/(hr ft^2) or less, mechanical cooling that has a capacity of 5 Btu/(hr ft^2 or less, or is maintained for a process environment as set forth in the definition of DIRECTLY CONDITIONED SPACE.

SERVICE WATER HEATING

is heating of water for sanitary purposes for human occupancy, other than for comfort heating.

SHADING

is the protection from heat gains because of direct solar radiation by permanently attached exterior devices or building elements, interior shading devices, glazing material, or adherent materials. Permanently attached means (a) attached with fasteners that require additional tools to remove (as opposed to clips, hooks, latches, snaps, or ties); or (b) required by the UBC for emergency egress to be removable from the interior without the use of tools.

SHADING COEFFICIENT (SC)

is the ratio of the solar heat gain through a fenestration product to the solar heat gain through an unshaded 1/8 inch thick clear double strength glass under the same set of conditions. For nonresidential, high-rise residential, and hotel/motel buildings, this shall exclude the effects of mullions, frames, sashes, and interior and exterior shading devices.

SITE SOLAR ENERGY

is natural daylighting, or thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site.

SKYLIGHT

is glazing having a slope less than 60 degrees from the horizontal with conditioned space below, except for purposes of complying with Section 151(f), where a skylight is glazing having a slope not exceeding 4.76 degrees (1:12) from the horizontal.

SKYLIGHT AREA
is the area of the surface of a skylight, plus the area of the frame, sash, and mullions.

SKYLIGHT TYPE
is a skylight assembly having a specific solar heat gain coefficient, whether translucent or transparent, and U-value.

SOLAR HEAT GAIN COEFFICIENT (SHGC)
is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.

SOURCE ENERGY
is the energy that is used at a site and consumed in producing and in delivering energy to a site, including, but not limited to, power generation, transmission, and distribution losses, and that is used to perform a specific function, such as space conditioning, lighting or water heating. Table 1-B contains the conversion factors for converting site to source energy.

SOUTH-FACING
is oriented to within 45 degrees of true south including 45^{o}00’00" west of south (SW), but excluding 45^{o}00’00" east of south (SE).

SPA
is a vessel that contains heated water, in which humans can immerse themselves, is not a pool, and is not a bathtub.

SPACE CONDITIONING SYSTEM
is a system that provides either collectively or individually heating, ventilating, or cooling within or associated with conditioned spaces in a building.

SMACNA
is the Sheet Metal and Air-conditioning Contractors National Association.

STAIRS, ACTIVE/INACTIVE
is a series of steps providing passage from one level of a building to another.

SUPPORT AREA
is a room or area used as a passageway, utility room, storage space, or other type of space associated with or secondary to the function of an occupancy that is listed in these regulations.

SYSTEM
is a combination of equipment, controls, accessories, interconnecting means, or terminal elements, by which energy is transformed to perform a specific function, such as space conditioning, service water heating, or lighting.

TASK-ORIENTED LIGHTING
is lighting that is designed specifically to illuminate a task location, and that is generally confined to the task location.

THEATER, MOTION PICTURE

is an assembly room, hall, or building with tiers of rising seats or steps for the showing of motion pictures.

THEATER, PERFORMANCE

is an assembly room, hall, or building with tiers of rising seats or steps for the viewing of dramatic performances, lectures, musical events and similar live performances.

THERMAL MASS

is solid or liquid material used to store heat for later heating use or for reducing cooling requirements.

THERMAL RESISTANCE (R)

is the resistance of a material or building component to the passage of heat in (hr x ft^2 x ^oF)/Btu.

THROW DISTANCE

is the distance between the luminaire and the center of the plane lit by the luminaire on a display.

TUNING

is a lighting control device that allows authorized personnel only to select a single light level within a continuous range.

UBC

is the 1994 edition of the state-adopted Uniform Building Code.

UL

is the Underwriters Laboratory.

UMC

is the 1997 edition of the state adopted Uniform Mechanical Code.

UNCONDITIONED SPACE

is enclosed space within a building that is not directly conditioned, indirectly conditioned or semi-conditioned space.

UNIT INTERIOR MASS CAPACITY (UIMC)

is the amount of effective heat capacity per unit of thermal mass, taking into account the type of mass material, thickness, specific heat, density and surface area.

U-VALUE

is the overall coefficient of thermal transmittance of a construction assembly, in Btu/(hr x ft^2 x ^oF), including air film resistance at both surfaces.

VAPOR BARRIER

is a material that has a permeance of one perm or less and that provides resistance to the transmission of water vapor.

VARIABLE AIR VOLUME (VAV) SYSTEM

is a space conditioning system that maintains comfort levels by varying the volume of conditioned air to the zones served.

VERY VALUABLE MERCHANDISE

is rare or precious objects, including, but not limited to, jewelry, coins, small art objects, crystal, china, ceramics, or silver, the selling of which involves customer inspection of very fine detail from outside of a locked case.

VISIBLE LIGHT TRANSMITTANCE (VLT)

is the ratio (expressed as a decimal) of visible light that is transmitted through a glazing material to the light that strikes the material.

VOCATIONAL ROOM

is a room used to provide training in a special skill to be pursued as a trade.

WALL TYPE

is a wall assembly having a specific heat capacity, framing type, and U-value.

WELL INDEX

is the ratio of the amount of visible light leaving a skylight well to the amount of visible light entering the skylight well and is calculated as follows:

(a) for rectangular wells:

$$\left(\frac{\text{Well height}\left(\text{well length} + \text{well width}\right)}{2 \times \text{well length} \times \text{well width}}\right)$$

; or

(b) for irregular shaped wells:

$$\left(\frac{\text{Well height} \times \text{well perimeter}}{4 \times \text{well area}}\right)$$

WEST-FACING

is oriented to within 45 degrees of true west, including 45^{o}00'00" north of due west (NW), but excluding 45^{o}00'00" south of west (SW).

WINDOW

is glazing that is not a skylight.

WINDOW AREA

is the area of the surface of a window, plus the area of the frame, sash, and mullions.

WINDOW TYPE

is a window assembly having a specific solar heat gain coefficient, relative solar heat gain, and U-value.

WINDOW WALL RATIO

is the ratio of the window area to the gross exterior wall area.

WOOD HEATER

is an enclosed wood burning appliance used for space heating and/or domestic water heating, and which meets the definition in Federal Register, Volume 52, Number 32, February 18, 1987.

WOOD STOVE

(See WOOD HEATER).

ZONE, LIGHTING

is a space or group of spaces within a building that has sufficiently similar requirements so that lighting can be automatically controlled in unison throughout the zone by an illumination controlling device or devices, and does not exceed one floor.

ZONE, SPACE CONDITIONING

is a space or group of spaces within a building with sufficiently similar comfort conditioning requirements so that comfort conditions, as specified in 144(b)3 or 150(h), as applicable, can be maintained throughout the zone by a single controlling device.

H: Residential Water Heating and Lighting

(Editor's Note: Appendix H is a combination of the Lighting portion of Chapter 2 and all of Chapter 6, Water Heating, from the ***Residential Manual****. References found in this appendix are a part of the* ***Residential Manual****.)*

SUMMARY

This chapter explains the relationship of water heating energy to the overall *Energy Efficiency Standards* (hereafter standards) compliance for a building. The Introduction briefly summarizes the *Water Heating Calculation Method* and explains when calculations and forms are required. This is followed by a more detailed discussion of the Basic Approach to the Method and step-by-step instructions on how to complete the water heating forms. Case studies outline the requirements for common and unusual water heating systems. Separate calculations and forms are explained for hydronic space and water heating systems. The chapter concludes with detailed descriptions of system components and installation criteria.

H.1 INTRODUCTION

Water heating energy use is important because it accounts for about a quarter of residential energy consumption, as illustrated in Figure H-1. This is the same percentage used statewide for residential space heating, and six times the amount used for residential cooling. Water heating energy may be an even higher percentage of the total energy consumption in small residences with lower space heating and cooling requirements.

Figure H-2 shows the general flow of energy from the fuel source through the water heating system to the end use in the building. *Total energy in* is a combination of source energy plus any auxiliary inputs, which equals total energy out. *Total energy out* includes energy lost through electric power generation and transmission to the residence, water heater recovery efficiency and standby loss, distribution system losses and finally, hot water delivered to fixtures and appliances (see *Source Energy* in the *Glossary*).

CHAPTER OVERVIEW:

Part	Topic	Page
H.1	**Introduction**	**H-1**
	Efficiency Terms Defined	H-1
	Water Heating Calculation Method	H-3
	Water Heater Type	H-4
	Auxiliary Inputs	H-4
	Distribution System	H-5
	When Are Water Heating Forms Required?	H-5
	Standard Water Heating Systems	H-5
	Pre-Calculated Non-Standard Systems	H-7
	Approved Computer Methods	H-7
	Water Heating Calculations And Energy Compliance	H-7
	Prescriptive Packages	H-7
	Performance Methods	H-7
	Water Heating Calculations for Additions	H-8
H.2	**Basic Approach**	**H-10**
H.3	**Instructions, Forms & Tables**	**H-12**
H.4	**Case Studies**	**H-28**
H.5	**Combined Hydronic Space and Water Heating**	**H-36**
H.6	**System Descriptions: Water Heaters, Auxiliary Inputs and Distribution Systems**	**H-36**
H.7	**Lighting**	**H-43**

Applicable sections of *the California Code of Regulations*, Title 24, Part 6: §150(j), 151(b), 151(f)8, 152.

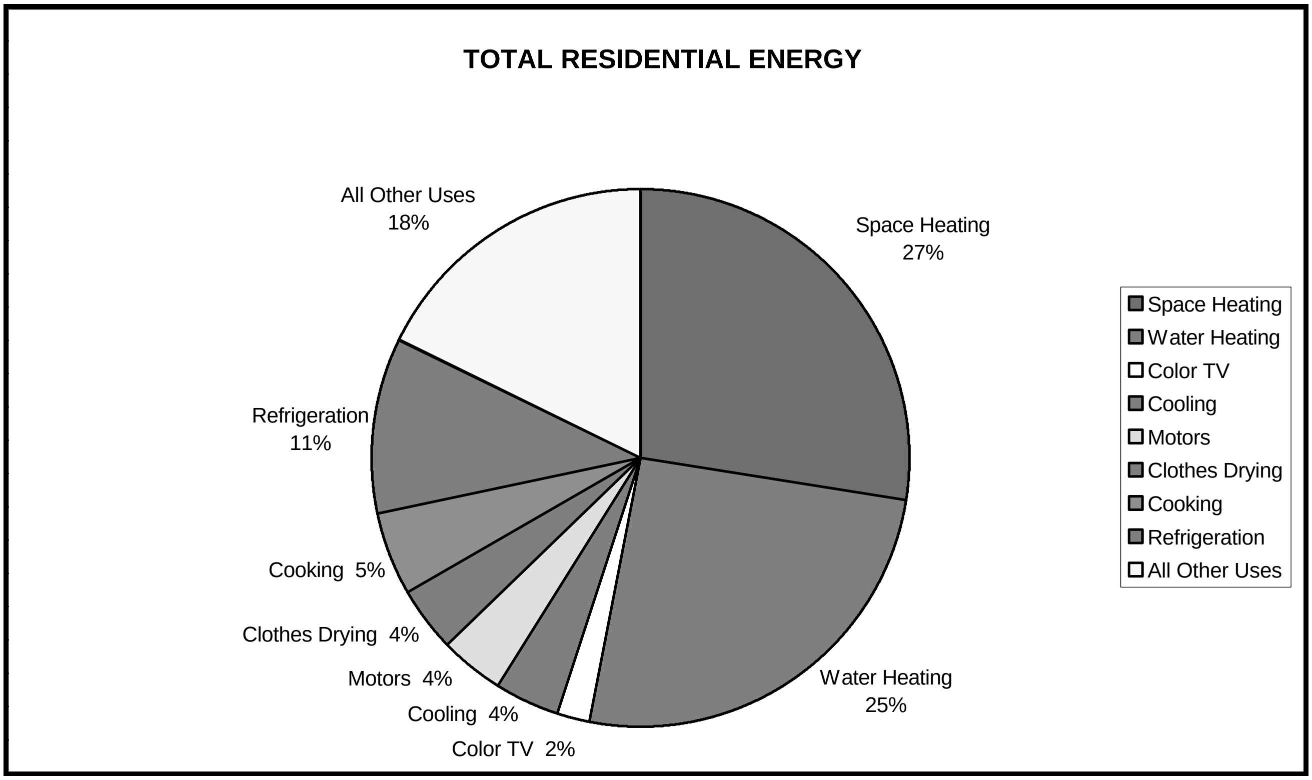


Figure H-1: Largest Residential Energy End

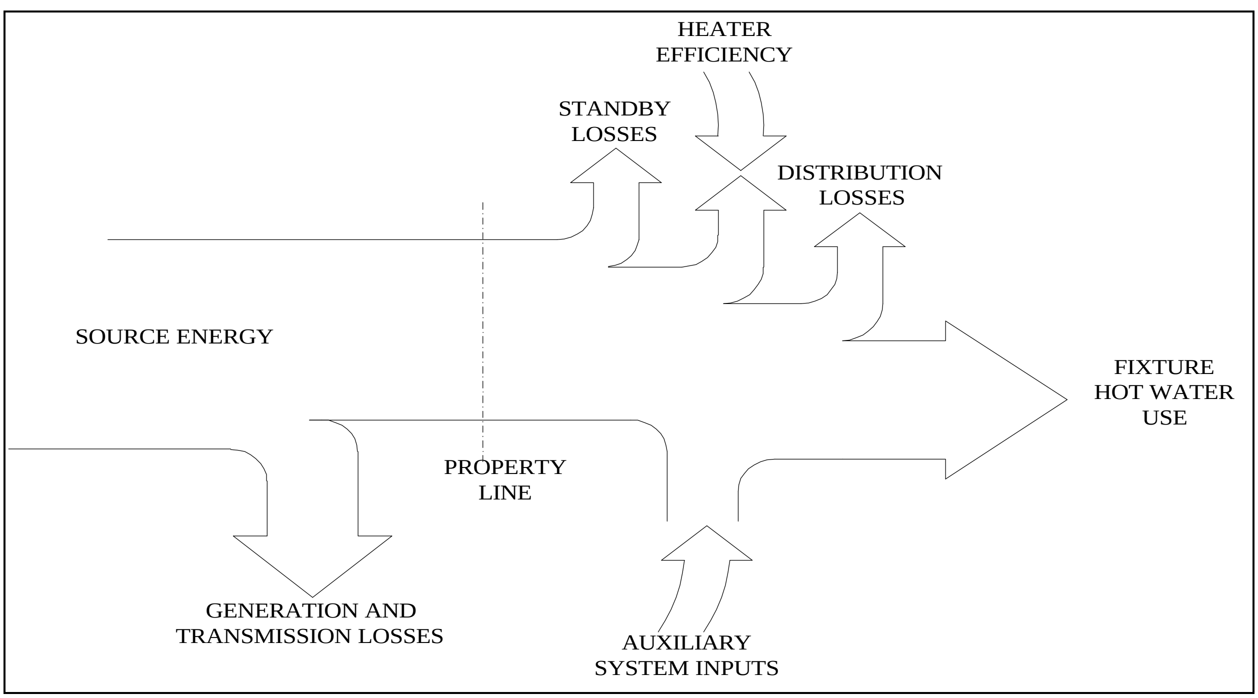


Figure H-2: Water Heater System Energy Flow Diagram

Energy Factor is a measure used for *Heater Efficiency* for most water heaters used in single family dwellings and includes standby losses, recovery efficiency (the ratio of energy output used to heat the water divided by energy input), and the tank volume. More efficient water heaters have a higher EF.

Standby Loss accounts for energy lost while storing heated water. It includes heat losses through the water heater tank walls, fittings and flue, if any, plus any pilot light energy. Standby loss depends on the design and insulation of the water heater, as well as the difference between the temperature of the water and that of the air around the tank. Water heating energy use can be reduced by decreasing standby loss. This can be done by selecting a more efficient heater.

The water heater efficiency rating for small heaters used in the water heating calculation method is the ***Energy Factor*** (EF) which combines tank volume, internal insulation, recovery efficiency and standby loss. The higher the EF the more efficient the water heater.

Recovery energy is the energy used to heat water, including the inefficiency (or efficiency loss) of the heater.

Recovery load is the amount of energy in hot water that the water needs to provide. It includes only the energy in the hot water that is used by the building occupant and the distribution losses.

Standby loss is over a quarter of a gas storage type water heater system's total energy use. When the system fuel is natural gas, there are no generation or transmission losses as are associated with electricity. Fuel type is very important in determining water heating energy use. While natural gas, LPG or oil can be burned directly to heat water, electricity is typically generated in a power plant far from the residence and then transmitted over power lines to the final end use. Approximately two thirds of the source energy used to generate electricity is lost in this process.

Any electric water heating system must automatically account for the inefficiency of the fuel type. Standard electric water heaters are not considered energy efficient for this reason. Electric heat pump water heaters, however, are closer to the efficiency of typical gas systems, because they use the outdoor air as a heat source in heating water (see *Heat Pump* in the *Glossary*).

See Table H-1a and Part H.6 for more information on water heater types.

All water heating systems must meet the mandatory measures explained in Chapter 2, and all water heaters installed in California must be certified to the Commission (see Chapter 2, Part 2.4 and Chapter 1, Part 1.6). Several values that are needed in the water heating method are listed in this directory.

Compliance/
Plan Check

Water Heating Calculation Method

The water heating calculation method estimates the amount of source energy used by any water heating system (the *Proposed Energy Use*) and compares it to the energy budget for water heating established by the standards (the *Standard Energy Use*).

Parts H.2 and H.3 give detailed information and instructions on using the water heating calculation method. Part H.3 includes blank copies of the various forms and the tables used in the calculations.

The calculation method looks at three components of each water heating system:

1. *Water Heater Type*
2. *Auxiliary Input*
   (nondepletable energy sources)
3. *Distribution System Type*

WATER HEATER TYPE

Water heater types which can be analyzed using the water heating calculation method are:

- Standard Water Heater
- Storage Gas
- Large Storage Gas
- Storage Electric
- Storage Heat Pump
- Instantaneous Gas
- Instantaneous Electric
- Indirect Gas
- Oil-Fired

See Table H-1a for brief descriptions of each water heater type and Part H.6 for more detailed descriptions plus installation criteria.

AUXILIARY INPUTS

Auxiliary inputs are other energy sources that contribute to overall water heating. The calculation method allows water heating credits for three auxiliary input types that save energy by using nondepletable energy sources:

- Passive Solar Water Heaters
- Active Solar Water Heaters
- Wood Stove Boilers

See Table H-1b for brief descriptions of each auxiliary input type and Part H.6 for more detailed descriptions plus installation criteria.

Table H-1a: Summary of System Components: Water Heaters

Water Heaters and Related Components	Description
Standard Water Heaters	Storage gas water heaters, 50 gallons or less (R-12 external insulation is a mandatory requirement for any water heater with an EF of less than 0.58).
Storage Gas	A gas water heater with a storage capacity of two gallons or more and a rated input of 75,000 Btu/hr or less.
Large Storage Gas	A storage gas water heater with greater than 75,000 Btuh input.
Storage Electric	An electric water heater with a storage capacity of two gallons or more.
Storage Heat Pump	An electric water heater that uses a compressor to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water.
Instantaneous Gas	A gas water heater that heats water on demand rather than storing preheated water in a tank. Manufacturer's specified storage capacity must be less than two gallons.
Instantaneous Electric	An electric water heater that heats water on demand rather than storing preheated water in a tank. Manufacturer's specified storage capacity must be less than two gallons.
Indirect Gas	A water heater consisting of a storage tank with no heating elements or combustion devices, connected via piping and recirculating pump to a heat source typically consisting of a gas or oil fired boiler.

Table H-1b: System Component Descriptions: Auxiliary Inputs

Auxiliary Systems	Description
Passive Solar Water Heaters	Systems which collect and store solar thermal energy for domestic water heating applications and do not require electricity to recirculate water through a solar collector.
Active Solar Water Heaters	Systems which collect and store solar thermal energy for domestic water heating applications requiring electricity to operate pumps or other components.
Wood Stove Boilers	Wood stoves equipped with heat exchangers for heating domestic hot water (see Figure H-8).

DISTRIBUTION SYSTEM

The water heating *distribution system* is the configuration of piping, pumps and controls which regulates delivery of hot water from the water heater to all end uses within the building. The water heating method gives credits for especially energy-efficient distribution systems, such as non-recirculating systems with pipe insulation, while assigning penalties for less energy-efficient systems, such as continuous recirculation systems with no controls (see Table H-6).

Distribution systems that may be analyzed are:

- Standard Distribution System
- Point of Use
- Hot Water Recovery
- Pipe Insulation
- Parallel Piping
- Recirculation: Continuous
- Recirculation: Temperature Controlled
- Recirculation: Time Controlled
- Recirculation: Time & Temperature Controlled
- Recirculation: Demand Pumping
- Combined Credits

Table H-1c gives brief definitions of all of the distribution system types listed above, while Part H.6 describes the systems in more detail and explains any required installation criteria.

WHEN ARE WATER HEATING FORMS REQUIRED?

Water heating forms must be provided only for non-standard systems that are not listed in Chapter 3 (for Prescriptive Packages).Table H-2 summarizes when water heating forms are required within the different compliance approaches.

STANDARD WATER HEATING SYSTEMS

If a proposed water heating system in a single family residence has no more than one *standard water heater* (as defined below) with a *standard distribution system*, then the water heating system need not be analyzed, but may be assumed to meet the water heating energy budget without requiring any additional forms or calculations. Compliance is demonstrated by simply listing the water heater on the Certificate of Compliance (CF-1R) Form.

The following water heater type is considered a *standard water heater:* storage gas water heater, 50 gallons or less, with a standard distribution system.

NOTE:

Any storage heat pump water heater, 50 gallons or less, with an EF of at least 1.8 in Climate Zones 1 - 15, or at least 2.6 in Climate Zone 16, and a standard distribution system meets the water heating energy budget.

Table H-1c: System Component Descriptions: Distribution Systems

Distribution Systems	Description
Standard	Standard system without any pumps for distributing hot water
Point of Use	System with no more than 8 feet horizontal distance between the water heater and hot water fixtures, except laundry. (Not used with central systems in multi-family buildings.)
Hot Water Recovery	System which reclaims hot water from the distribution piping by drawing it back to the water heater or other insulated storage tank. (Not used with central systems in multi-family buildings.)
Pipe Insulation	R-4 (or greater) insulation applied to 3/4 inch or larger, non-recirculating hot water mains in addition to insulation required by the standards, Section 150(j) (first five feet from water heater on both hot and cold water pipes).
Parallel Piping	Individual pipes from the water heater to each point of use.
Recirculation: Continuous	Distribution system using a pump to recirculate hot water to branch piping though a looped hot water main with no control of the pump, such that water flow is continuous. (Not used with instantaneous water heaters.) Pipe insulation is required.
Recirculation: Temperature	Recirculation system that uses temperature controls to cycle pump operation to maintain recirculated water temperatures within certain limits. (Not used with instantaneous water heaters.) Pipe insulation is required.
Recirculation: Time	Recirculation system that uses a timer control to cycle pump operation based on time of day. (Not used with instantaneous water heaters.) Pipe insulation is required.
Recirculation: Time/Temp	Recirculation system that uses both temperature and timer controls to regulate pump operation. (Not used with instantaneous water heaters.) Pipe insulation is required.
Recirculation: Demand	Recirculation system that uses brief pump operation to recirculate hot water to fixtures just prior to hot water use when a demand for hot water is indicated. (Not used with instantaneous water heaters or with central systems in multi-family buildings.)
Recirculation/Demand w/ Hot Water Recovery	Combined system consisting of Recirculation: Demand and Hot Water Recovery.
Recirculation/Demand w/ Pipe Insulation	Combined system consisting of Recirculation: Demand and Pipe Insulation.

A *standard distribution system* is one which does not incorporate a pump to recirculate hot water, and does not take credit for any special design features. A distribution system normally eligible for energy credits, such as one with pipe insulation, may be modeled as standard (i.e., no credits) to avoid water heating calculations.

See Part H.6 for more detailed descriptions of standard water heaters and distribution systems, including installation criteria.

Table H-2: When Are Water Heating Forms Required?

Compliance Method	Standard	Pre-Calculated Non-Standard	Other Non-Standard
	Water Heating System Type		
Prescriptive Packages	No	No [1,2]	Yes[4]
Performance Method[4]	No	n/a	No [1,4]

Notes:

1 No water heating forms are required, except to document solar collector systems and/or wood stoves.

2 Pre-calculated non-standard systems are listed in Chapter 3.

3 Approved programs perform water heating calculations internally; forms need not be submitted.

4 See Tables H-3 and H-4 for a summary of water heating forms and compliance scenarios.

PRE-CALCULATED NON-STANDARD SYSTEMS

To simplify compliance with the prescriptive packages the Commission has developed lists of non-standard water heating systems that may be used without submitting water heating calculations.

Systems pre-calculated and shown to meet or exceed the efficiency of a standard system are found in Chapter 3, Table 3-4.

APPROVED COMPUTER METHODS

Approved computer programs perform water heating calculations internally, making water heating compliance forms unnecessary. However, other documentation may be required to support water heating credits for auxiliary inputs or other unique system components used for compliance.

WATER HEATING CALCULATIONS AND ENERGY COMPLIANCE

The basic structure of the water heating calculation method is to:

(1) Calculate the *Proposed Energy Use* of the proposed water heating system

(2) Determine the *Standard Energy Use* (the energy budget)

(3) Compare the *Proposed Energy Use* to the *Standard Energy Use*

PRESCRIPTIVE PACKAGES

When demonstrating energy compliance for a building using the Prescriptive Packages, the proposed energy use for a water heating system must be less than the standard energy budget (see Chapter 3, Part 3.2). This requirement may be met by:

- Installing a standard water heating system;
- Installing an approved non-standard system as listed in Chapter 3, Table 3-4; or,
- Completing the calculations and forms contained in Part H.3 to verify that the proposed energy use is less than the standard energy use.

PERFORMANCE METHODS

When demonstrating energy compliance for a building using an approved performance method, the building's total (combined) space conditioning and water heating energy consumption cannot exceed the sum of the total space conditioning and water heating energy budgets (see Chapter 4, and Part 4.2).

When using an approved computer program, water heating compliance is calculated internally within the program.

If the building has a standard water heating system as defined above, the Proposed Energy Use is equal to the Standard Energy Use in the performance methods.

WATER HEATING CALCULATIONS FOR ADDITIONS

There are three typical situations for water heating systems in building additions:

(1) The addition uses the existing water heating system. No new water heater is added.

If no new water heater is added, the addition may be analyzed by itself without requiring water heating calculations. If the addition is analyzed using the existing-plus-addition method (performance), then either the existing water heating system may be modeled as is or it may be assumed to be a standard water heating system (see Chapter 6, Part 6.3) (Use the same modeling assumptions for all calculations.)

(2) A new water heater, installed to replace the existing water heater, serves the entire existing building plus the addition, and there is no increase in the number of water heaters in the building.

In this case water heating calculations are not required because the total number of water heaters does not increase. The new water heater serves as a replacement; for the purpose of compliance analysis, it may be assumed to be a standard water heater.

(3) A new water heater (or heaters) is added with the addition, resulting in an increase in the number of water heaters (see below).

Energy Code

Additions that Increase the Total Number of Water Heaters (Section 152(a), Exception No. 3)

If the addition will increase the total number of water heaters in the building, one of the following types of water heaters may be installed to comply with Section 152(a)1. or Section 152(a)2.A, and Section 152 (c):

(1) A gas storage non-recirculating water heating system that does not exceed 50 gallons capacity; or

(2) If no natural gas is connected to the building, an electric storage water heater that does not exceed 50 gallons capacity, has an energy factor not less than 0.90; or

(3) A water heating system determined by the Executive Director to use no more energy than the one specified in (1) above; or if no natural gas is connected to the building, a water heating system determined by the Executive Director to use no more energy than the one specified in (2) above.

For prescriptive compliance with Section 152(a)1., the water heating systems requirement in Section 151(f)8. shall not apply. For performance compliance for the addition alone, only the space conditioning budgets of Section 151(b)2. shall be used; the water heating budgets of Section 151(b)1. shall not apply.

The performance approach for the existing building and the addition in Section 152(a)2.B may be used to show compliance, regardless of the type of water heater installed.

Compliance/
Plan Check

Additions that Increase the Total Number of Water Heaters

When there is an increase in the number of water heaters, the addition may be analyzed using any of the compliance approaches under certain conditions. Addition alone compliance may be used if:

(a) The additional water heater is either a 50-gallon or less, gas storage, nonrecirculating water heater or equivalent (see Chapter 6, Table 6-2) that also meets the mandatory requirements (see Chapter2);

(b) The home does not have natural gas available and the additional water heater is either a 50-gallon or less electric water heater with an EF of 0.90 or greater or equivalent (see Chapter 6, Table 6-2);

If the conditions in (a) or (b) are met, water heating calculations are not required with any of the compliance approaches, and no credit or penalty is allowed. Computer compliance calculations will show proposed energy use for water heating to be equal to standard energy use.

Existing-plus-addition compliance may be used when a new water heating system is proposed which is not described in (a) and (b) above, is not found in Chapter 6, Table 6-2, or to take credit for a more efficient water heating system.

See Examples H-8, H-9 and H-12 in Part H.4, and Chapter 6 for more information on compliance of water heaters associated with additions.

Inspection

Water Heating Inspection

Check that the number and types of water heater systems installed, as indicated on the CF-6R and check to see that this corresponds to the approved CF-1R. The distribution system is also significant and must correspond to plan specifications. For example:

- If the plans indicate the presence of a hot water recovery system, it must be installed.
- If a recirculation system is installed, verify that it was accounted for in the compliance documentation (CF-1R) and check for any required controls (e.g., demand pump, timer).
- If a point of use credit is specified, the water heater must be no further than 8 feet from all hot water outlets (excluding washing machines).

The chart below summarizes the different distribution system types and lists whether each one is a credit or a penalty as compared with the standard distribution system.

Verify the make and model number of the installed water heater unit matches that listed on the Installation Certificate (CF-6R).

If the water heater has an EF of less than 0.58, an R-12 water heater blanket is required (internal insulation cannot be used to satisfy this mandatory requirement). For water heaters with 0.58 EF or higher, no insulation blanket is required. The blanket should be securely attached around the water heater. The top of the water heater should not be insulated and a cutout in the blanket should be provided for combustion air intake.

Water Heating Distribution System Credits and Penalties

Distribution System	**Credit or Penalty**
Hot Water Recovery	Credit
Point of Use	Credit
Pipe Insulation	Credit
Parallel Piping	Credit
Recirculation:	
No Control	Penalty
Time	Penalty
Temperature	Penalty
Time/Temperature	Credit
Demand	Credit

H.2 BASIC APPROACH

Water Heating Budget (Section 151(b)1)

Energy Code

Water heating budgets. The budgets for water heating systems are those calculated from Equation No. 1-N.

EQUATION NO. 1-N
ANNUAL WATER HEATING BUDGET (AWB):

For dwelling units less than 2500 ft²:

$$AWB\ (kBtu/yr.\text{-}ft^2) = \frac{\underline{16370}}{CFA} + 4.85$$

For dwelling units equal to or greater than 2500 ft²:

$$AWB\ (kBtu/yr.\text{-}ft^2) = \frac{\underline{26125}}{CFA}$$

Where CFA = the building's conditioned floor area in square feet.

The annual water heating budget calculated from Equation No. 1-N may be met by either:

A. Calculating the energy consumption of the proposed water heating system using an approved calculation method without an external insulation wrap or

B. Installing any gas storage type non-recirculating water heating system that does not exceed 50 gallons of capacity, and that meets the minimum standards specified in the Appliance Efficiency Standards.

NOTE: Storage gas water heaters with an energy factor of less than 0.58 must be externally wrapped with insulation having an installed thermal resistance of R-12 or greater in accordance with Section 150(j).

Compliance/
Plan Check

Water Heating Budget

As outlined in Part H.1, the water heating method involves the calculation of the *Proposed Energy Use* of the proposed system, and the determination of the *Standard Energy Use* for the dwelling unit being analyzed (see form DHW-1).

The standard water heating energy use per dwelling unit is dependent on the total conditioned floor area of the dwelling unit. Allowable water heating energy use per dwelling unit increases with an increase in floor area. However, 26,125 kBtu/yr-unit is the maximum standard water heating energy use for dwelling units larger than 2,500 square feet (Section 151(b)1 of the standards).

Standard energy use is assumed to be climate-independent. It is based on the energy use of a federally rated minimum efficiency 50 gallon gas water heater (EF 0.525) with a standard distribution system (see Part H.6).

Presented as a hand method in this chapter, water heating calculations use a series of forms and tables included at the end of Part H.3. The forms and tables used are selected according to the specific proposed water heating system. Tables H-3 and H-4 summarize the forms as well as their application in a range of compliance situations.

The water heating method can be used to analyze water heating energy use of:

- A specific single dwelling unit;
- An average dwelling unit in a multi-family building; or,
- Each different dwelling unit in a multi-family building.

NOTE:

When multi-family water heaters are *shared* by more than one dwelling unit, compliance must be based on the average of the square feet of the dwelling units served by each (different) shared water heater.

Table H-3: Summary of Water Heating Forms		
Number	**Name/Function**	**Application**
DHW-1	Water Heating Worksheet	Non-standard water heating system
DHW-2A	Water Heating for Single Family w/ Multiple Heaters	Single-family dwelling unit with more than one water heater
DHW-2B	Water Heating for Multi-Family	Multi-family building
DHW-3	Large or Indirect Water Heater Worksheet	Large Storage Gas or Indirect Gas heater (see Part H.6)
DHW-4	Auxiliary Input Worksheet	Passive solar, active solar or wood stove boiler
DHW-5	Combined Hydronic Space and Water Heating	Hydronic system serving both space heating and water heating (see Part H.5)

Table H-4: Summary of Compliance Scenarios

Compliance Scenario		Forms Submitted
a.	One Standard System Per Dwelling Unit	None
b.	Pre-Calculated System (see Chapters 3 & 4)	None
c.	One Non-standard System Per Dwelling Unit (other than pre-calculated systems)	DHW-1
d.	Single Family Dwelling w/Multiple Heaters (other than pre-calculated systems)	DHW-1, DHW-2A
e.	Multi-Family Building	DHW-1, DHW-2B
f.	Solar or Wood Stove (Auxiliary Input)	DHW-4
g.	Combined Hydronic Space and Water Heating	DHW-5
h.	Additions (see Chapter 7)	Same as a, b, c, d, e, f or g above

The compliance methodology has three steps:

1. Determine the *Adjusted Recovery Load* to be satisfied by the water heating system. The *Standard Recovery Load* (from Table H-5) may be modified by *distribution piping system credits or penalties* (from Table H-6) and/or a *solar energy credit* (from DHW-4).

2. Determine the *Proposed Energy Use* of the water heating system. The *Basic Energy Use* (from Table H-7 according to heater type) may be modified by a *wood stove boiler credit* (from DHW-4).

3. Determine the *Standard Energy Use* of the dwelling unit(s) (from Table H-5).

Water heating compliance depends on a comparison of the Proposed Energy Use and the Standard Energy Use:

- **Prescriptive:** The Proposed Energy Use must be less than or equal to the Standard Energy Use for compliance of the water heating system.
- **Performance Methods:** The difference between Proposed and Standard Water Heating Energy Use is either a *credit* resulting in a *lower kBtu/sf-yr* of total proposed energy use, or a *penalty* resulting in a *higher kBtu/sf-y*r of total energy use.

Water Heating in the Performance Methods

Using the performance approach, *energy tradeoffs* can be made between water heating and space conditioning energy use.

If the proposed water heating energy use is greater than the standard energy use, the water heating system and building comply as long as:

- The total proposed design energy use, in kBtu/sf-yr, is the same or less than the total standard design energy budget using a computer method as explained in Chapter 5.

H.3 INSTRUCTIONS, FORMS & TABLES

Compliance/
Plan Check

Instructions

The instructions presented in this part provide a step-by-step description for each worksheet and form. To see completed sample worksheets for different water heating systems, see Part H.4. For an overview of which forms apply to which compliance scenarios, refer to Table H-4.

The worksheet for Combined Hydronic Space and Water Heating, DHW-5, is contained in Part H.5.

Heater type data is contained in the Commission's listing of certified water heaters. Data on water heaters, for use with a database program is also available from the Commission's Web site at:

ftp://energy.ca.gov/pub/efftech/appliance/

DHW-1, Water Heating Worksheet

Complete the DHW-1 form whenever there is a non-standard water heating system (see Parts H.1 and H.6). You may calculate up to three different heater types per sheet. If you have more than three different types, use additional copies of the worksheet.

The section of the worksheet entitled *Energy Use Calculation* refers to tables included at the end of this part.

Title Block

- Enter **Project Title** and **Date**.
- Enter the **Number of Different Water Heater Types** (this value may not necessarily be the same as the *total* number of individual water heaters in the building.)
- Enter the **Total No. of Water Heaters**.
- Enter the total **Conditioned Floor Area (CFA)** of the dwelling unit, in square feet. When multi-family water heaters are *shared* by more than one dwelling unit, compliance must be based on the average of the square feet of the dwelling units served by each (different) shared water heater. Enter this average dwelling unit CFA here.

Heater Type Data

For each column, enter the heater type number (e.g., "Heater # 1 Data".) To identify which water on the plans matches these calculations.

A. Indicate the **Water Heater Type**. For a full listing of heater type descriptions and installation criteria, see Part H.6. If the water heater is part of a hydronic system, see Part H.5.

NOTE:

Oil-fired water heaters are considered gas water heaters for the purpose of the water heating calculations.

B. List the **Manufacturer**.

C. List the **Model No.**

The next set of values (lines D, E, F and G) must be taken from the Commission's listing of Certified Water Heaters*.*

D. Enter the **Energy Factor**. If indirect Gas or Large Gas Storage water heater, leave blank.

E. Enter the actual capacity of the heater in **Gallons**.

F. For Instantaneous Gas heater type, enter **Pilot Btu/hr**.

G. For Instantaneous Gas heater type only, enter **Thermal** (**Recovery) Efficiency** (also used on form DHW-3).

H. Renewable energy sources such as solar or a wood stove are considered **Auxiliary Input** to the system. Indicate with a check mark if either applies. For determining credit for these sources, see instructions for form DHW-4. For a full description of auxiliary inputs, see Part H.6.

I. Indicate the **Distribution System**. For a full listing of distribution descriptions and installation criteria, see Part H.6. If the distribution system is part of a hydronic system, see Part H.5.

Energy Use Calculation

All values entered in lines 1a through 1d, lines 2a through 2c, and line 3 are in million Btu/year per dwelling unit (MBtu/yr-unit).

1a. Enter the **Standard Recovery Load** from Table H-5 based on the total conditioned floor area of the dwelling unit.

1b. For a "Standard" distribution system, enter zero (0).

For other distribution system types, select **Distribution Credit** (+) or **Penalty** (-) from Table H-5 or H-6 based on standard recovery load (line 1a).

Pipe insulation credit can only be taken with non-recirculating systems and demand recirculating systems.

1c. If there is solar Auxiliary Input (line H), determine the **Solar Energy Credit** on form DHW-4 for active or passive solar systems (see DHW-4, line 1 or 9). Otherwise, enter zero (0).

1d. Subtract credits to calculate the **Adjusted Recovery Load** (subtract lines 1b and 1c from line 1a). Note that when line 1b is negative, line 1d increases.

2a. Based upon the Water Heater Type (line A), find the **Basic Energy Use** as follows:

Storage Gas	Table H-7A
Storage Electric	Table H-7B
Storage Heat Pump	Table H-7C
Instantaneous Gas	Table H-7D
Instantaneous Electric	Table H-7D
Indirect Gas	DHW-3
Large Storage Gas	DHW-3

The tables use values listed on this worksheet such as Energy Factor (line D), Adjusted Recovery Load (line 1d), Pilot Btu/hr and Recovery Efficiency.

NOTE:

No interpolation is allowed in Table H-7. Go into the rows and columns in those tables using the table values closest to the actual values.

2b. If there is a wood stove Auxiliary Input (line I), determine the **Wood Stove Boiler Credit** from form DHW-4 (line 10). Otherwise, enter zero (0).

2c. Subtract credits to calculate the **Proposed Energy Use** (subtract line 2b from line 2a).

Standard Energy Use

3. Find the **Standard Energy Use** from Table H-5 using the total conditioned floor area of the dwelling unit. Enter the value on line 3.

4. In the prescriptive compliance approach (Chapter 3, Part 3.2), *the proposed water heating system complies if line 2c is less than or equal to line 3*.

DHW-2A, Water Heating for Single Family with Multiple Heaters

If you are completing the DHW-1 form for a single family unit with more than one water heater, you must also complete the DHW-2A form.

Title Block

- Enter **Project Title** and **Date**.

Single Family Project Data

1. Enter the **Number of different water heater types** (this may not necessarily be the same as the *total* number of water heaters in the building.)

2. Enter the **Total conditioned floor area** of the dwelling unit.

3a, 3b & 3c.
Enter the **Number of Heaters** for each **Heater Type Number**, **Manufacturer** and **Model Number** listed on DHW-1.

4. The **Total Number of Water Heaters** is the sum of lines 3a, 3b and 3c.

5. Enter the **Standard Recovery Load** from Table H-5 based on line 2, total conditioned floor area.

6. Calculate and enter the **Recovery Load per heater**, which is line 5 divided by line 4. Enter this value on DHW-1, line 1a, for each heater type. Complete DHW-1 calculations through line 2c for each heater type.

7. Calculate and enter the **Proposed Energy Use** for **Heater Type #1**, which is DHW-1 Heater Type #1 line 2c times line 3a.

8. Calculate and enter the **Proposed Energy Use** for **Heater Type #2**, which is DHW-1 Heater Type #2 line 2c times line 3b.

9. Calculate and enter the **Proposed Energy Use** for **Heater Type #3**, which is DHW-1 Heater Type #3 line 2c times line 3c.

10. Calculate and enter the **Total Proposed Energy Use**, which is the sum of lines 7, 8 and 9.

11. Enter the **Standard Energy Use** from Table H-5 using line 2, total conditioned floor area.

Compliance

12. In the prescriptive compliance approach (see Chapter 3), *the proposed water heating system complies if line 10 is equal to or less than line 11.*

DHW-2B, Water Heating for Multi-Family

Complete the DHW-2B form for any multi-family project. *The DHW-1 worksheet must also be completed whenever the DHW-2B form is submitted.*

Title Block

- Enter **Project Title** and **Date**.

Multi-Family Project Data

1. Enter the **Number of dwelling units**.

2. Enter the **Total conditioned floor area** of the building.

3. Calculate and enter the **Average floor area** per dwelling unit, which is line 2 divided by line 1.

4. Indicate which analytical method is used to calculate Proposed Energy Use: **Average Dwelling Unit** or **Individual Dwelling Unit**.

For "Individual Dwelling Unit" analysis, complete only lines 1 through 5, and attach a DHW-1 form with a Heater Type # for each individual unit.

5. Indicate which System configuration is being installed in the building: **Individual Heaters** (one per dwelling unit) or **Shared Heaters** (multiple dwelling units per heater).

   If Individual Heaters, follow instructions for lines 9a through 11a.

   If Shared Heater(s), complete lines 9b - 13b, and follow instructions on line 13b.

6a, 6b, 6c & 6d.
Enter the **Number of Heaters** for each **Heater Type Number**, **Manufacturer** and **Model Number** listed. For Individual Heaters, also enter the volume in **Gallons** for **Each** heater, and for the **Total** number of heaters of that type; enter the **Energy Factor** for **Each** heater, and the **Total** value (which is the number of heaters times the EF). Enter the Thermal (Recovery) Efficiency for each heater and the Total value (number of heaters time the Thermal Efficiency).

7a. Enter the **Total** number of heaters, which is the sum of lines 6a, 6b and 6c.

The following items (lines 7b, 7c, 7d, 8a and 8b) are calculated only for Individual Heaters.

7b. Enter the **Total** gallons of all heaters.

7c. Enter the **Total** of the Energy Factors.

7d. Enter the **Total** of the Thermal Efficiencies.

8a. Calculate and enter the **Average** gallons per heater, which is line 7b divided by line 7a.

8b. Calculate and enter the **Average** Energy Factor per heater, which is line 7c divided by line 7a.

8c. Calculate and enter the Average Thermal Efficiency per heater, which is line 7d divided by line 7a.

Individual Heaters

9a. Transfer the value from line 8a to DHW-1 line E (gallons).

10a. Transfer the value from line 8b to DHW-1 line D (Energy Factor).

11a. Transfer the value from line 8c to DHW-1 line G (Thermal Efficiency)

12. Check compliance on DHW-1 for average dwelling unit and average water heater.

Shared Heater(s)

9b. Calculate and enter the **Average Unit Recovery Load**, which is DHW-1 line 1d.

10b. Calculate and enter the **Total Adjusted Recovery Load**, which is line 1 times line 9b.

11b. Enter the **Basic Energy Use** from Table H-7, or from DHW-3 line 9 based on line 10b.

12b. Calculate and enter the **Average Unit Building Energy Use**, which is transferred from DHW-1 line 2a.

13b. Verify compliance on DHW-1 for average dwelling unit.

14. In the prescriptive compliance approach (see Chapter 3), *the proposed water heating system complies if DHW-1 line 2c is less than or equal to DHW-1 line 3*.

DHW-3, Large Storage Gas or Indirect Gas Worksheet

Complete the DHW-3 for any project that includes a large storage gas heater or an indirect gas heater (as explained in Part H.6). *The DHW-1 worksheet must also be completed whenever the DHW-3 form is submitted.*

Title Block

- Enter **Project Title** and **Date**.

Indirect Gas Water Heaters

1. Enter the **Storage tank Manufacturer and Model Number.**

2. Enter the **Boiler or Instantaneous Water Heater Manufacturer and Model Number.**

3. Enter the **Storage tank insulation R-value**: The R-value integral with (internal to) the **Tank**; any **External** insulation R-value; and the **Total** of the two.

4. Enter the **Storage tank volume** in gallons.

5. Find the **Boiler AFUE or Instantaneous Water Heater Recovery Efficiency** in the appropriate appliance directory or database and enter on Line 5 in decimal fraction form (e.g., 0.78).

6. Enter the **Adjusted Recovery Load** on line 6 from DHW-1 Line 1d.

7. Using tank volume (Line 4) and Total R-Value (Line 5), determine **Jacket Loss** in MMBtu/yr from Table H-7E and enter on line 7.

8. Enter **Pilot energy** (Btu/hr) from appliance directory or database on line 8. Enter zero (0) for no pilot, or 800 if pilot exists but energy use is not listed in the appliance database.

9. Using the equation listed, calculate Basic Energy Use and enter the value on line 9. Also enter the value on DHW-1 Line 2a or DHW-2B Line 11b.

Large Storage Gas Water Heaters (>75,000 Btuh Input)

1. Enter the **Water Heater Manufacturer.**

2. Enter the **Water Heater Model No.**

3. Enter the **Storage tank insulation R-value**: The R-value integral with (internal to) the **Tank**; any **External** insulation R-value; and the **Total** of the two.

4. Enter the **Storage tank volume** in gallons.

5. Enter the **Water Heater Recovery Efficiency** from the appliance database and enter on Line 5 in decimal fraction form (e.g. 0.78).

6. Enter the **Adjusted Recovery Load**, from DHW-1 Line 1d or from DHW-2B Line 10b, on Line 6.
7. Enter **Standby loss %** from the appliance database on line 8. (For example, enter "3.2" for 3.2 percent.)

8. Using the equation listed, calculate Basic Energy Use and enter the value on line 9. Also, enter the value on DHW-1 Line 2a or on DHW-2b Line 11b.

DHW-4, Auxiliary Input Worksheet

Complete the DHW-4 for any project that includes active solar, passive solar or a wood stove as an Auxiliary Input (as explained in Part H.6).

Active Solar Credit

To receive credit for an active solar water heating system, it is necessary to calculate the solar contribution or Solar Fraction from an analysis by a certified version of the program called "f-Chart" (see Appendix F.)

Active solar credits are calculated on a "per dwelling unit" basis, and they include a 20 percent source energy adjustment for pumping and collector piping losses.

The f-Chart input parameters listed in Tables H-8 and H-10 are fixed for compliance. *Those fixed values must be used in all compliance calculations.*

1. Multiply:

   (Solar Fraction) x (Adjusted Recover Load) x (0.80)

   Where:

   Solar Fraction = "FDWH" from f-Chart; Adjusted Recovery Load is taken from DHW-1, line 1d.

The active solar credit calculated on line 1 is then entered on DHW-1, line 1c.

Passive Solar Credit

Passive solar water heating credits are derived from test results published by the Solar Rating and Certification Corporation (SRCC) in conjunction with climate zone specific weather data for California. (See Part H.6 for information on obtaining SRCC data.)

Climate zone insolation data, used in calculating line 5 of the DHW-4 worksheet, is listed in Table H-9. Climate zone ambient air temperature and water main temperature data, used in calculating line 6 and line 7 of the DHW-4 worksheet, is listed in Table H-10.

Line 8 is calculated only if the passive solar system uses electric resistance freeze protection.

The passive solar credit entered on DHW-1 line 1c cannot exceed the greater of the net recovery load which is line 1a minus line 1b on DHW-1, or 3 million BTU per year.

Wood Stove Boiler Credit

Internal wood stove boilers (WSBs) can supply the majority of daily water heating energy during the heating season. Some WSBs require a recirculating pump during wood stove operation.

Table H-11 may be used to compute wood stove boiler credit with or without a recirculating pump. DHW-1 must be completed through line 2a before WSB credit is computed.

WSB credit factors in Table H-11 vary by climate zone. A WSB credit is computed by multiplying the appropriate credit factor by DHW-1 line 2a (Basic Energy Use).

DHW-4 line 10 is entered on DHW-1 line 2b.

NOTE:

As tabulated in Table H-11, the credit for WSBs with recirculating pumps is 90 percent of the credit without pumps based on a base case 85 watt pump applied to a 1700 ft^2 house and adjusted for electric source energy.

DHW-5, Combined Hydronic Space and Water Heating

Complete the DHW-5 for any project that includes a combined hydronic space and water heating system (as explained in Parts H.5 and 7.9) to calculate the AFUE. The DHW-5 is also used to calculate the adjusted AFUE (accounting for pipe losses) when a space heating boiler is also used for water heating.

The DHW-1 worksheet must also be completed whenever the DHW-5 form is submitted.

If water heating is provided by a dedicated (separate) hydronic space heating system, complete the DHW-1 form only.

Storage Gas

1. Enter the **Recovery Efficiency, Thermal Efficiency, or Annual Fuel Utilization Efficiency (AFUE)** (decimal) of the water heater or boiler.
2. Enter the calculated **Average Hourly Pipe Loss**, from Line 8.
3. Enter the **Rated Input** of the water heater.
4. Determine the **Effective AFUE** of the system, by first dividing Line 2 by Line 3, then subtracting that value from Line 1. This value is used for prescriptive compliance.

Storage Electric

1. Enter the calculated **Average Hourly Pipe Loss**, from Line 8.
2. Enter the **Rated Input** of the water heater.
3. Enter the **Pump Watts** of the water heater and all other pumps associated with the system.
4. Calculate **Term A** from Lines 1 and 2. Multiply Line 2 by 3.413, then divide Line 1 by this value. Subtract the result from 1.

5. Calculate **Term B** from Lines 2 and 3. Mul-0tiply Line 3 by 1000, then divide Line 3 by this value, and add 1.

6. Calculate the **Effective HSPF (no fan)** by first dividing Line 4 by Line 5, then multiplying the result by 3.413. This value is used in the packages.

7. Calculate the **Effective HSPF (with fan)** by first dividing 1 by Line 6, then adding 0.00H. Next divide the result into 1.017. This value is used in the packages.

Heat Pump

1. Enter the **Energy Factor** (decimal) of the water heater.

2. Enter the **Average Hourly Pipe Loss** from Line 8.

3. Enter the **Rated Input** of the water heater.

4. Determine the **Recovery Efficiency** of the water heater. Divide 1 by Line 1, then subtract 0.1175. Divide the result into 1.

5. Enter the **Climate Zone Adjustment** value from the table on the form.

6. Calculate the **Effective HSPF (no fan)** by first multiplying 3.413 by Line 3, then dividing this value into Line 2. Next subtract this value from the value resulting from dividing Line 4 by Line 5. Multiply this result by 3.413. This value is used in the packages.

7. Calculate the **Effective HSPF (with fan)** by first dividing 1 by Line 6, then adding 0.005. Next divide the result into 1.017. This value is used in the packages.

Pipe Loss Worksheet

1. Include **Description(s)** of any piping with more than 10 feet of pipe in unconditioned space between supply and distribution systems.

2. Enter **Pipe Loss Rate** for type(s) of pipe from table.

3. Enter the **Pipe Length** of each pipe outside conditioned space.

9. Calculate **Total Pipe Loss** by multiplying pipe loss rate by pipe length.

5. Total all pipe losses from 4.

6. Divide by 8760 to determine the **Average Hourly Pipe Loss (kBtu/hr)**, and enter on Line 8.

If the **Pipe Losses** section is not applicable (less than 10 feet of pipe in unconditioned space), enter a value of zero on Line 8.

Table H-5: Standard Recovery Load and Standard Energy Use1

Floor Area	Standard Recovery Load	Standard Energy Use	Standard Floor Area	Standard Recovery Load	Energy Use
< 111	6.4	16.9	726 - 775	8.8	20.0
111 - 130	6.5	17.0	776 - 825	9.0	20.3
131 - 150	6.5	17.0	826 - 875	9.2	20.5
151 - 170	6.6	17.1	876 - 925	9.4	20.7
171 - 190	6.7	17.2	926 - 975	9.5	21.0
191 - 210	6.8	17.3	976 - 1050	9.8	21.3
211 - 230	6.8	17.4	1051 - 1150	10.1	21.7
231 - 250	6.9	17.5	1151 - 1250	10.5	22.2
251 - 270	7.0	17.6	1251 - 1350	10.9	22.7
271 - 290	7.1	17.7	1351 - 1450	11.3	23.2
291 - 310	7.1	17.8	1451 - 1550	11.6	23.6
311 - 330	7.2	17.9	1551 - 1650	12.0	24.1
331 - 350	7.3	18.0	1651 - 1750	12.4	24.6
351 - 370	7.3	18.1	1751 - 1850	12.8	25.1
371 - 390	7.4	18.2	1851 - 1950	13.2	25.6
391 - 410	7.5	18.3	1951 - 2050	13.6	26.1
411 - 430	7.6	18.4	2051 - 2150	14.0	26.6
431 - 450	7.6	18.5	2151 - 2250	14.4	27.0
451 - 470	7.7	18.6	2251 - 2350	14.8	27.5
471 - 490	7.8	18.7	2351 - 2500	15.3	28.1
491 - 525	7.9	18.8	> 2500	15.6	28.5
526 - 575	8.0	19.0			
576 - 625	8.2	19.3			
626 - 675	8.4	19.5			
676 - 726	8.6	19.8			

1. Based on Residential Water Heating Study (CEC Contract #400-88-003; ASHRAE Service Water Heating Design, 1993 ASHRAE Handbook of HVAC Systems and Applications

Table H-6A Distribution System Credit/Penalty[1] for Single Family Dwellings (per worksheet)

Standard Recovery Load	POU	HWR	Pipe Insulation	Recirculation Systems Time/Temp	Demand	Time	Temp	Cont
	0.82	0.82	0.92	0.96	0.98	1.28	1.05	1.52
< 6.3	1.1	1.1	0.5	0.3	0.1	-1.8	-0.3	-3.3
6.3 - 6.99	1.2	1.2	0.5	0.3	0.1	-1.8	-0.3	-3.4
7.0 - 7.49	1.3	1.3	0.6	0.3	0.1	-2.0	-0.4	-3.7
7.5 - 7.99	1.4	1.4	0.6	0.3	0.2	-2.2	-0.4	-4.0
8.0 - 8.49	1.5	1.5	0.7	0.3	0.2	-2.3	-0.4	-4.3
8.5 - 8.99	1.6	1.6	0.7	0.3	0.2	-2.4	-0.4	-4.5
9.0 - 9.49	1.7	1.7	0.7	0.4	0.2	-2.6	-0.5	-4.8
9.5 - 9.99	1.7	1.7	0.8	0.4	0.2	-2.7	-0.5	-5.0
10.0 - 10.99	1.8	1.8	0.8	0.4	0.2	-2.9	-0.5	-5.3
11.0 - 11.99	2.0	2.0	0.9	0.4	0.2	-3.1	-0.6	-5.8
12.0 - 12.99	2.2	2.2	1.0	0.5	0.2	-3.4	-0.6	-6.3
13.0 - 13.99	2.4	2.4	1.1	0.5	0.3	-3.7	-0.7	-6.9
14.0 - 15.99	2.6	2.6	1.1	0.6	0.3	-4.0	-0.7	-7.4
16.0 - 17.99	2.9	2.9	1.3	0.6	0.3	-4.5	-0.8	-8.4
18.0 - 19.99	3.3	3.3	1.5	0.7	0.4	-5.1	-0.9	-9.5
20.0 - 21.99	3.6	3.6	1.6	0.8	0.4	-5.7	-1.0	-10.5
22.0 - 23.99	4.0	4.0	1.8	0.9	0.4	-6.2	-1.1	-11.5
24.0 - 25.99	4.4	4.4	1.9	1.0	0.5	-6.8	-1.2	-12.6
26.0+	4.8	4.8	2.1	1.1	0.5	-7.4	-1.3	-13.7

Table H-6B Distribution System Credit/Penalty[1] for Multi Family Dwellings (per worksheet)								
					Recirculation Systems			
Standard Recovery Load	**POU**	**HWR**	**Pipe Insulation**	**Time/Temp**	**Demand**	**Time**	**Temp**	**Cont**
	1	1	0.92	1.52	1.52	1.52	1.05	1.52
< 6.3	0.0	0.0	0.5	-3.3	-3.3	-3.3	-0.3	-3.3
6.3 - 6.99	0.0	0.0	0.5	-3.4	-3.4	-3.4	-0.3	-3.4
7.0 - 7.49	0.0	0.0	0.6	-3.7	-3.7	-3.7	-0.4	-3.7
7.5 - 7.99	0.0	0.0	0.6	-4.0	-4.0	-4.0	-0.4	-4.0
8.0 - 8.49	0.0	0.0	0.7	-4.3	-4.3	-4.3	-0.4	-4.3
8.5 - 8.99	0.0	0.0	0.7	-4.5	-4.5	-4.5	-0.4	-4.5
9.0 - 9.49	0.0	0.0	0.7	-4.8	-4.8	-4.8	-0.5	-4.8
9.5 - 9.99	0.0	0.0	0.8	-5.0	-5.0	-5.0	-0.5	-5.0
10.0 - 10.99	0.0	0.0	0.8	-5.3	-5.3	-5.3	-0.5	-5.3
11.0 - 11.99	0.0	0.0	0.9	-5.8	-5.8	-5.8	-0.6	-5.8
12.0 - 12.99	0.0	0.0	1.0	-6.3	-6.3	-6.3	-0.6	-6.3
13.0 - 13.99	0.0	0.0	1.1	-6.9	-6.9	-6.9	-0.7	-6.9
14.0 - 15.99	0.0	0.0	1.1	-7.4	-7.4	-7.4	-0.7	-7.4
16.0 - 17.99	0.0	0.0	1.3	-8.4	-8.4	-8.4	-0.8	-8.4
18.0 - 19.99	0.0	0.0	1.5	-9.5	-9.5	-9.5	-0.9	-9.5
20.0 - 21.99	0.0	0.0	1.6	-10.5	-10.5	-10.5	-1.0	-10.5
22.0 - 23.99	0.0	0.0	1.8	-11.5	-11.5	-11.5	-1.1	-11.5
24.0 - 25.99	0.0	0.0	1.9	-12.6	-12.6	-12.6	-1.2	-12.6
26.0+	0.0	0.0	2.1	-13.7	-13.7	-13.7	-1.3	-13.7

1. Hot water recovery and pipe insulation credits may only be applied to non-recirculating systems and demand recirculating systems. All other recirculating systems must have pipe insulation as explained in Part 6.6.

Table H-7A: Basic Energy Use (BEU) - Storage Gas Heater [no interpolation]

Adjusted Recov- Load	Energy Factor																						
	0.45	**0.46**	**0.47**	**0.48**	**0.49**	**0.50**	**0.51**	**0.52**	**0.53**	**0.54**	**0.55**	**0.56**	**0.57**	**0.58**	**0.60**	**0.62**	**0.64**	**0.66**	**0.68**	**0.70**	**0.74**	**0.78**	**0.82**
3.0	19.9	18.5	17.3	16.2	15.3	14.4	13.7	13.0	12.4	11.8	11.3	10.8	10.4	10.0	9.3	8.7	8.1	7.7	7.2	6.8	6.2	5.7	5.2
3.2	19.6	18.3	17.2	16.2	15.3	14.5	13.8	13.1	12.6	12.0	11.5	11.1	10.6	10.3	9.6	8.9	8.4	7.9	7.5	7.1	6.5	5.9	5.5
3.4	19.4	18.2	17.2	16.2	15.4	14.6	14.0	13.3	12.8	12.2	11.8	11.3	10.9	10.5	9.8	9.2	8.7	8.2	7.8	7.4	6.7	6.2	5.7
3.6	19.3	18.2	17.2	16.3	15.5	14.8	14.2	13.6	13.0	12.5	12.0	11.6	11.2	10.8	10.1	9.5	9.0	8.5	8.1	7.7	7.0	6.4	5.9
3.8	19.3	18.2	17.3	16.5	15.7	15.0	14.4	13.8	13.2	12.7	12.3	11.8	11.4	11.1	10.4	9.8	9.2	8.8	8.3	7.9	7.3	6.7	6.2
4.0	19.3	18.3	17.4	16.6	15.9	15.2	14.6	14.0	13.5	13.0	12.5	12.1	11.7	11.3	10.7	10.1	9.5	9.0	8.6	8.2	7.5	6.9	6.4
4.2	19.4	18.4	17.6	16.8	16.1	15.4	14.8	14.2	13.7	13.2	12.8	12.4	12.0	11.6	10.9	10.3	9.8	9.3	8.9	8.5	7.8	7.2	6.7
4.4	19.5	18.6	17.7	17.0	16.3	15.6	15.0	14.5	14.0	13.5	13.1	12.6	12.3	11.9	11.2	10.6	10.1	9.6	9.1	8.7	8.0	7.4	6.9
4.6	19.6	18.7	17.9	17.2	16.5	15.9	15.3	14.7	14.2	13.8	13.3	12.9	12.5	12.2	11.5	10.9	10.3	9.8	9.4	9.0	8.3	7.7	7.1
4.8	19.8	18.9	18.1	17.4	16.7	16.1	15.5	15.0	14.5	14.0	13.6	13.2	12.8	12.4	11.8	11.2	10.6	10.1	9.7	9.3	8.5	7.9	7.4
5.0	19.9	19.1	18.3	17.6	17.0	16.4	15.8	15.3	14.8	14.3	13.9	13.5	13.1	12.7	12.0	11.4	10.9	10.4	9.9	9.5	8.8	8.1	7.6
5.2	20.1	19.3	18.5	17.8	17.2	16.6	16.0	15.5	15.0	14.6	14.1	13.7	13.3	13.0	12.3	11.7	11.1	10.6	10.2	9.8	9.0	8.4	7.8
5.4	20.3	19.5	18.8	18.1	17.4	16.9	16.3	15.8	15.3	14.8	14.4	14.0	13.6	13.2	12.6	12.0	11.4	10.9	10.4	10.0	9.3	8.6	8.1
5.6	20.5	19.7	19.0	18.3	17.7	17.1	16.6	16.0	15.6	15.1	14.7	14.3	13.9	13.5	12.8	12.2	11.7	11.2	10.7	10.3	9.5	8.9	8.3
5.8	20.7	19.9	19.2	18.6	17.9	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.8	13.1	12.5	11.9	11.4	11.0	10.5	9.8	9.1	8.5
6.0	20.9	20.2	19.5	18.8	18.2	17.6	17.1	16.6	16.1	15.6	15.2	14.8	14.4	14.0	13.4	12.8	12.2	11.7	11.2	10.8	10.0	9.3	8.7
6.2	21.2	20.4	19.7	19.1	18.4	17.9	17.3	16.8	16.3	15.9	15.5	15.1	14.7	14.3	13.6	13.0	12.5	11.9	11.5	11.0	10.2	9.6	9.0
6.4	21.4	20.6	20.0	19.3	18.7	18.1	17.6	17.1	16.6	16.2	15.7	15.3	14.9	14.6	13.9	13.3	12.7	12.2	11.7	11.3	10.5	9.8	9.2
6.6	21.6	20.9	20.2	19.6	19.0	18.4	17.9	17.4	16.9	16.4	16.0	15.6	15.2	14.8	14.2	13.5	13.0	12.4	12.0	11.5	10.7	10.0	9.4
6.8	21.9	21.1	20.5	19.8	19.2	18.7	18.1	17.6	17.1	16.7	16.3	15.9	15.5	15.1	14.4	13.8	13.2	12.7	12.2	11.8	10.9	10.2	9.6
7.0	22.1	21.4	20.7	20.1	19.5	18.9	18.4	17.9	17.4	17.0	16.5	16.1	15.7	15.4	14.7	14.1	13.5	12.9	12.5	12.0	11.2	10.5	9.8
7.2	22.3	21.6	21.0	20.3	19.7	19.2	18.6	18.1	17.7	17.2	16.8	16.4	16.0	15.6	14.9	14.3	13.7	13.2	12.7	12.2	11.4	10.7	10.1
7.4	22.6	21.9	21.2	20.6	20.0	19.4	18.9	18.4	17.9	17.5	17.1	16.7	16.3	15.9	15.2	14.6	14.0	13.4	12.9	12.5	11.6	10.9	10.3
7.6	22.8	22.1	21.5	20.8	20.3	19.7	19.2	18.7	18.2	17.8	17.3	16.9	16.5	16.2	15.5	14.8	14.2	13.7	13.2	12.7	11.9	11.1	10.5
7.8	23.1	22.4	21.7	21.1	20.5	20.0	19.4	18.9	18.5	18.0	17.6	17.2	16.8	16.4	15.7	15.1	14.5	13.9	13.4	13.0	12.1	11.4	10.7
8.0	23.3	22.6	22.0	21.4	20.8	20.2	19.7	19.2	18.7	18.3	17.8	17.4	17.0	16.7	16.0	15.3	14.7	14.2	13.7	13.2	12.3	11.6	10.9
8.2	23.6	22.9	22.2	21.6	21.0	20.5	20.0	19.5	19.0	18.5	18.1	17.7	17.3	16.9	16.2	15.6	15.0	14.4	13.9	13.4	12.6	11.8	11.1
8.4	23.8	23.1	22.5	21.9	21.3	20.7	20.2	19.7	19.3	18.8	18.4	18.0	17.6	17.2	16.5	15.8	15.2	14.7	14.2	13.7	12.8	12.0	11.3
8.6	24.1	23.4	22.8	22.1	21.6	21.0	20.5	20.0	19.5	19.1	18.6	18.2	17.8	17.4	16.7	16.1	15.5	14.9	14.4	13.9	13.0	12.2	11.6
8.8	24.3	23.7	23.0	22.4	21.8	21.3	20.7	20.2	19.8	19.3	18.9	18.5	18.1	17.7	17.0	16.3	15.7	15.2	14.6	14.1	13.2	12.5	11.8
9.0	24.6	23.9	23.3	22.7	22.1	21.5	21.0	20.5	20.0	19.6	19.1	18.7	18.3	18.0	17.2	16.6	16.0	15.4	14.9	14.4	13.5	12.7	12.0
9.2	24.8	24.2	23.5	22.9	22.3	21.8	21.3	20.8	20.3	19.8	19.4	19.0	18.6	18.2	17.5	16.8	16.2	15.6	15.1	14.6	13.7	12.9	12.2
9.4	25.1	24.4	23.8	23.2	22.6	22.0	21.5	21.0	20.5	20.1	19.7	19.2	18.8	18.5	17.7	17.1	16.4	15.9	15.3	14.8	13.9	13.1	12.4
9.6	25.4	24.7	24.0	23.4	22.9	22.3	21.8	21.3	20.8	20.3	19.9	19.5	19.1	18.7	18.0	17.3	16.7	16.1	15.6	15.1	14.1	13.3	12.6
9.8	25.6	24.9	24.3	23.7	23.1	22.6	22.0	21.5	21.1	20.6	20.2	19.7	19.3	19.0	18.2	17.6	16.9	16.3	15.8	15.3	14.4	13.5	12.8
10.0	25.9	25.2	24.6	23.9	23.4	22.8	22.3	21.8	21.3	20.9	20.4	20.0	19.6	19.2	18.5	17.8	17.2	16.6	16.0	15.5	14.6	13.8	13.0
10.5	26.5	25.8	25.2	24.6	24.0	23.5	22.9	22.4	22.0	21.5	21.0	20.6	20.2	19.8	19.1	18.4	17.8	17.2	16.6	16.1	15.1	14.3	13.5
11.0	27.1	26.5	25.8	25.2	24.7	24.1	23.6	23.1	22.6	22.1	21.7	21.2	20.8	20.4	19.7	19.0	18.4	17.7	17.2	16.6	15.7	14.8	14.0
11.5	27.8	27.1	26.5	25.9	25.3	24.7	24.2	23.7	23.2	22.7	22.3	21.9	21.5	21.1	20.3	19.6	18.9	18.3	17.7	17.2	16.2	15.3	14.5
12.0	28.4	27.7	27.1	26.5	25.9	25.4	24.8	24.3	23.8	23.4	22.9	22.5	22.1	21.7	20.9	20.2	19.5	18.9	18.3	17.8	16.8	15.9	15.1
12.5	29.0	28.4	27.7	27.1	26.6	26.0	25.5	25.0	24.5	24.0	23.5	23.1	22.7	22.3	21.5	20.8	20.1	19.5	18.9	18.3	17.3	16.4	15.6
13.0	29.7	29.0	28.4	27.8	27.2	26.6	26.1	25.6	25.1	24.6	24.1	23.7	23.3	22.9	22.1	21.3	20.7	20.0	19.4	18.9	17.8	16.9	16.0
13.5	30.3	29.6	29.0	28.4	27.8	27.2	26.7	26.2	25.7	25.2	24.7	24.3	23.9	23.5	22.7	21.9	21.2	20.6	20.0	19.4	18.3	17.4	16.5
14.0	30.9	30.3	29.6	29.0	28.4	27.9	27.3	26.8	26.3	25.8	25.3	24.9	24.5	24.0	23.2	22.5	21.8	21.1	20.5	19.9	18.9	17.9	17.0
14.5	31.6	30.9	30.3	29.6	29.0	28.5	27.9	27.4	26.9	26.4	25.9	25.5	25.1	24.6	23.8	23.1	22.4	21.7	21.1	20.5	19.4	18.4	17.5
15.0	32.2	31.5	30.9	30.3	29.7	29.1	28.5	28.0	27.5	27.0	26.5	26.1	25.6	25.2	24.4	23.6	22.9	22.2	21.6	21.0	19.9	18.9	18.0
15.5	32.8	32.1	31.5	30.9	30.3	29.7	29.1	28.6	28.1	27.6	27.1	26.7	26.2	25.8	25.0	24.2	23.5	22.8	22.2	21.5	20.4	19.4	18.5
16.0	33.4	32.7	32.1	31.5	30.9	30.3	29.8	29.2	28.7	28.2	27.7	27.3	26.8	26.4	25.5	24.8	24.0	23.3	22.7	22.1	20.9	19.9	19.0
16.5	34.0	33.4	32.7	32.1	31.5	30.9	30.3	29.8	29.3	28.8	28.3	27.8	27.4	26.9	26.1	25.3	24.6	23.9	23.2	22.6	21.4	20.4	19.5
17.0	34.7	34.0	33.3	32.7	32.1	31.5	30.9	30.4	29.9	29.4	28.9	28.4	28.0	27.5	26.7	25.9	25.1	24.4	23.8	23.1	22.0	20.9	19.9
17.5	35.3	34.6	33.9	33.3	32.7	32.1	31.5	31.0	30.5	30.0	29.5	29.0	28.5	28.1	27.2	26.4	25.7	25.0	24.3	23.6	22.5	21.4	20.4
18.0	35.9	35.2	34.5	33.9	33.3	32.7	32.1	31.6	31.1	30.5	30.0	29.6	29.1	28.6	27.8	27.0	26.2	25.5	24.8	24.2	23.0	21.9	20.9
18.5	36.5	35.8	35.1	34.5	33.9	33.3	32.7	32.2	31.6	31.1	30.6	30.1	29.7	29.2	28.3	27.5	26.8	26.0	25.3	24.7	23.5	22.4	21.4
19.0	37.1	36.4	35.7	35.1	34.5	33.9	33.3	32.8	32.2	31.7	31.2	30.7	30.2	29.8	28.9	28.1	27.3	26.5	25.8	25.2	24.0	22.8	21.8
19.5	37.7	37.0	36.3	35.7	35.1	34.5	33.9	33.3	32.8	32.3	31.8	31.3	30.8	30.3	29.4	28.6	27.8	27.1	26.4	25.7	24.5	23.3	22.3
20.0	38.3	37.6	36.9	36.3	35.7	35.1	34.5	33.9	33.4	32.8	32.3	31.8	31.3	30.9	30.0	29.1	28.4	27.6	26.9	26.2	24.9	23.8	22.8
21.0	39.5	38.8	38.1	37.4	36.8	36.2	35.6	35.1	34.5	34.0	33.4	32.9	32.5	32.0	31.1	30.2	29.4	28.6	27.9	27.2	25.9	24.8	23.7
22.0	40.7	40.0	39.3	38.6	38.0	37.4	36.8	36.2	35.6	35.1	34.6	34.1	33.6	33.1	32.2	31.3	30.5	29.7	28.9	28.2	26.9	25.7	24.6

Table H-7B: Basic Energy Use (BEU) - Storage Electric Heater [no interpolation]

Adjust-edRe-Load	Energy Factor																						
	0.77	**0.78**	**0.79**	**0.80**	**0.81**	**0.82**	**0.83**	**0.84**	**0.85**	**0.86**	**0.87**	**0.88**	**0.89**	**0.90**	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.96**	**0.97**	**0.98**	**0.99**
3.0	22.4	21.1	20.0	19.0	18.1	17.2	16.5	15.8	15.2	14.6	14.0	13.5	13.0	12.6	12.2	11.8	11.5	11.1	10.8	10.5	10.2	9.9	9.7
3.2	23.0	21.8	20.7	19.7	18.8	18.0	17.2	16.5	15.9	15.3	14.7	14.2	13.8	13.3	12.9	12.5	12.1	11.8	11.5	11.1	10.8	10.6	10.3
3.4	23.6	22.4	21.3	20.4	19.5	18.7	17.9	17.2	16.6	16.0	15.4	14.9	14.4	14.0	13.6	13.2	12.8	12.4	12.1	11.8	11.5	11.2	10.9
3.6	24.2	23.1	22.0	21.1	20.2	19.4	18.6	17.9	17.3	16.7	16.1	15.6	15.1	14.7	14.2	13.8	13.5	13.1	12.7	12.4	12.1	11.8	11.5
3.8	24.8	23.7	22.7	21.7	20.9	20.1	19.3	18.6	18.0	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.7	13.4	13.1	12.7	12.4	12.1
4.0	25.5	24.4	23.3	22.4	21.6	20.8	20.0	19.3	18.7	18.1	17.5	17.0	16.5	16.0	15.6	15.2	14.8	14.4	14.0	13.7	13.4	13.1	12.8
4.2	26.1	25.0	24.0	23.1	22.2	21.4	20.7	20.0	19.4	18.8	18.2	17.7	17.2	16.7	16.3	15.8	15.4	15.0	14.7	14.3	14.0	13.7	13.4
4.4	26.7	25.6	24.7	23.8	22.9	22.1	21.4	20.7	20.1	19.5	18.9	18.4	17.8	17.4	16.9	16.5	16.1	15.7	15.3	15.0	14.6	14.3	14.0
4.6	27.3	26.3	25.3	24.4	23.6	22.8	22.1	21.4	20.7	20.1	19.6	19.0	18.5	18.0	17.6	17.1	16.7	16.3	15.9	15.6	15.2	14.9	14.6
4.8	28.0	26.9	26.0	25.1	24.3	23.5	22.7	22.1	21.4	20.8	20.2	19.7	19.2	18.7	18.2	17.8	17.4	17.0	16.6	16.2	15.9	15.5	15.2
5.0	28.6	27.6	26.6	25.7	24.9	24.1	23.4	22.7	22.1	21.5	20.9	20.4	19.8	19.3	18.9	18.4	18.0	17.6	17.2	16.8	16.5	16.1	15.8
5.2	29.2	28.2	27.3	26.4	25.6	24.8	24.1	23.4	22.7	22.1	21.6	21.0	20.5	20.0	19.5	19.1	18.6	18.2	17.8	17.5	17.1	16.7	16.4
5.4	29.8	28.8	27.9	27.0	26.2	25.5	24.7	24.1	23.4	22.8	22.2	21.7	21.1	20.6	20.2	19.7	19.3	18.9	18.5	18.1	17.7	17.4	17.0
5.6	30.4	29.5	28.5	27.7	26.9	26.1	25.4	24.7	24.1	23.5	22.9	22.3	21.8	21.3	20.8	20.3	19.9	19.5	19.1	18.7	18.3	18.0	17.6
5.8	31.0	30.1	29.2	28.3	27.5	26.8	26.0	25.4	24.7	24.1	23.5	23.0	22.4	21.9	21.4	21.0	20.5	20.1	19.7	19.3	18.9	18.6	18.2
6.0	31.6	30.7	29.8	29.0	28.2	27.4	26.7	26.0	25.4	24.7	24.2	23.6	23.1	22.6	22.1	21.6	21.2	20.7	20.3	19.9	19.5	19.2	18.8
6.2	32.3	31.3	30.4	29.6	28.8	28.0	27.3	26.7	26.0	25.4	24.8	24.2	23.7	23.2	22.7	22.2	21.8	21.4	20.9	20.5	20.2	19.8	19.4
6.4	32.9	31.9	31.1	30.2	29.4	28.7	28.0	27.3	26.6	26.0	25.4	24.9	24.3	23.8	23.3	22.9	22.4	22.0	21.6	21.2	20.8	20.4	20.0
6.6	33.5	32.5	31.7	30.8	30.1	29.3	28.6	27.9	27.3	26.7	26.1	25.5	25.0	24.5	24.0	23.5	23.0	22.6	22.2	21.8	21.4	21.0	20.6
6.8	34.1	33.2	32.3	31.5	30.7	29.9	29.2	28.6	27.9	27.3	26.7	26.2	25.6	25.1	24.6	24.1	23.7	23.2	22.8	22.4	22.0	21.6	21.2
7.0	34.7	33.8	32.9	32.1	31.3	30.6	29.9	29.2	28.6	27.9	27.3	26.8	26.2	25.7	25.2	24.7	24.3	23.8	23.4	23.0	22.6	22.2	21.8
7.2	35.3	34.4	33.5	32.7	31.9	31.2	30.5	29.8	29.2	28.6	28.0	27.4	26.9	26.3	25.8	25.4	24.9	24.4	24.0	23.6	23.2	22.8	22.4
7.4	35.9	35.0	34.1	33.3	32.6	31.8	31.1	30.5	29.8	29.2	28.6	28.0	27.5	27.0	26.5	26.0	25.5	25.1	24.6	24.2	23.8	23.4	23.0
7.6	36.5	35.6	34.7	33.9	33.2	32.4	31.7	31.1	30.4	29.8	29.2	28.7	28.1	27.6	27.1	26.6	26.1	25.7	25.2	24.8	24.4	24.0	23.6
7.8	37.0	36.2	35.3	34.5	33.8	33.1	32.4	31.7	31.1	30.4	29.8	29.3	28.7	28.2	27.7	27.2	26.7	26.3	25.8	25.4	25.0	24.6	24.2
8.0	37.6	36.8	35.9	35.2	34.4	33.7	33.0	32.3	31.7	31.1	30.5	29.9	29.4	28.8	28.3	27.8	27.3	26.9	26.4	26.0	25.6	25.2	24.8
8.2	38.2	37.4	36.5	35.8	35.0	34.3	33.6	32.9	32.3	31.7	31.1	30.5	30.0	29.4	28.9	28.4	28.0	27.5	27.0	26.6	26.2	25.8	25.4
8.4	38.8	37.9	37.1	36.4	35.6	34.9	34.2	33.5	32.9	32.3	31.7	31.1	30.6	30.0	29.5	29.0	28.6	28.1	27.7	27.2	26.8	26.4	26.0
8.6	39.4	38.5	37.7	37.0	36.2	35.5	34.8	34.2	33.5	32.9	32.3	31.7	31.2	30.7	30.1	29.7	29.2	28.7	28.3	27.8	27.4	27.0	26.6
8.8	40.0	39.1	38.3	37.6	36.8	36.1	35.4	34.8	34.1	33.5	32.9	32.4	31.8	31.3	30.8	30.3	29.8	29.3	28.9	28.4	28.0	27.6	27.2
9.0	40.5	39.7	38.9	38.1	37.4	36.7	36.0	35.4	34.7	34.1	33.5	33.0	32.4	31.9	31.4	30.9	30.4	29.9	29.5	29.0	28.6	28.2	27.8
9.2	41.1	40.3	39.5	38.7	38.0	37.3	36.6	36.0	35.3	34.7	34.1	33.6	33.0	32.5	32.0	31.5	31.0	30.5	30.1	29.6	29.2	28.8	28.4
9.4	41.7	40.9	40.1	39.3	38.6	37.9	37.2	36.6	35.9	35.3	34.7	34.2	33.6	33.1	32.6	32.1	31.6	31.1	30.7	30.2	29.8	29.4	29.0
9.6	42.3	41.4	40.7	39.9	39.2	38.5	37.8	37.2	36.5	35.9	35.3	34.8	34.2	33.7	33.2	32.7	32.2	31.7	31.3	30.8	30.4	30.0	29.5
9.8	42.8	42.0	41.2	40.5	39.8	39.1	38.4	37.8	37.1	36.5	35.9	35.4	34.8	34.3	33.8	33.3	32.8	32.3	31.9	31.4	31.0	30.5	30.1
10.0	43.4	42.6	41.8	41.1	40.4	39.7	39.0	38.4	37.7	37.1	36.5	36.0	35.4	34.9	34.4	33.9	33.4	32.9	32.4	32.0	31.6	31.1	30.7
10.5	44.8	44.0	43.3	42.5	41.8	41.1	40.5	39.8	39.2	38.6	38.0	37.5	36.9	36.4	35.9	35.4	34.9	34.4	33.9	33.5	33.0	32.6	32.2
11.0	46.2	45.4	44.7	44.0	43.3	42.6	41.9	41.3	40.7	40.1	39.5	39.0	38.4	37.9	37.4	36.8	36.4	35.9	35.4	35.0	34.5	34.1	33.7
11.5	47.6	46.8	46.1	45.4	44.7	44.0	43.4	42.8	42.2	41.6	41.0	40.4	39.9	39.3	38.8	38.3	37.8	37.4	36.9	36.4	36.0	35.6	35.1
12.0	49.0	48.2	47.5	46.8	46.1	45.5	44.8	44.2	43.6	43.0	42.5	41.9	41.3	40.8	40.3	39.8	39.3	38.8	38.4	37.9	37.5	37.0	36.6
12.5	50.3	49.6	48.9	48.2	47.6	46.9	46.3	45.7	45.1	44.5	43.9	43.4	42.8	42.3	41.8	41.3	40.8	40.3	39.8	39.4	38.9	38.5	38.1
13.0	51.7	51.0	50.3	49.6	49.0	48.3	47.7	47.1	46.5	45.9	45.4	44.8	44.3	43.7	43.2	42.7	42.2	41.8	41.3	40.8	40.4	40.0	39.5
13.5	53.1	52.4	51.7	51.0	50.4	49.7	49.1	48.5	47.9	47.3	46.8	46.2	45.7	45.2	44.7	44.2	43.7	43.2	42.8	42.3	41.8	41.4	41.0
14.0	54.4	53.7	53.0	52.4	51.7	51.1	50.5	49.9	49.3	48.8	48.2	47.7	47.2	46.6	46.1	45.6	45.1	44.7	44.2	43.8	43.3	42.9	42.4
14.5	55.7	55.1	54.4	53.8	53.1	52.5	51.9	51.3	50.8	50.2	49.6	49.1	48.6	48.1	47.6	47.1	46.6	46.1	45.7	45.2	44.8	44.3	43.9
15.0	57.1	56.4	55.7	55.1	54.5	53.9	53.3	52.7	52.2	51.6	51.1	50.5	50.0	49.5	49.0	48.5	48.0	47.6	47.1	46.7	46.2	45.8	45.3
15.5	58.4	57.7	57.1	56.5	55.9	55.3	54.7	54.1	53.6	53.0	52.5	52.0	51.4	50.9	50.4	50.0	49.5	49.0	48.5	48.1	47.7	47.2	46.8
16.0	59.7	59.1	58.4	57.8	57.2	56.6	56.1	55.5	54.9	54.4	53.9	53.4	52.9	52.4	51.9	51.4	50.9	50.4	50.0	49.5	49.1	48.7	48.2
16.5	61.0	60.4	59.8	59.2	58.6	58.0	57.4	56.9	56.3	55.8	55.3	54.8	54.3	53.8	53.3	52.8	52.3	51.9	51.4	51.0	50.5	50.1	49.7
17.0	62.3	61.7	61.1	60.5	59.9	59.4	58.8	58.3	57.7	57.2	56.7	56.2	55.7	55.2	54.7	54.2	53.8	53.3	52.9	52.4	52.0	51.6	51.1
17.5	63.6	63.0	62.4	61.8	61.3	60.7	60.2	59.6	59.1	58.6	58.1	57.6	57.1	56.6	56.1	55.6	55.2	54.7	54.3	53.9	53.4	53.0	52.6
18.0	64.9	64.3	63.7	63.1	62.6	62.0	61.5	61.0	60.5	59.9	59.4	59.0	58.5	58.0	57.5	57.1	56.6	56.2	55.7	55.3	54.9	54.4	54.0
18.5	66.1	65.6	65.0	64.5	63.9	63.4	62.8	62.3	61.8	61.3	60.8	60.3	59.9	59.4	58.9	58.5	58.0	57.6	57.1	56.7	56.3	55.9	55.5
19.0	67.4	66.9	66.3	65.8	65.2	64.7	64.2	63.7	63.2	62.7	62.2	61.7	61.2	60.8	60.3	59.9	59.4	59.0	58.6	58.1	57.7	57.3	56.9
19.5	68.7	68.1	67.6	67.1	66.5	66.0	65.5	65.0	64.5	64.0	63.6	63.1	62.6	62.2	61.7	61.3	60.8	60.4	60.0	59.6	59.2	58.7	58.3
20.0	70.0	69.4	68.9	68.4	67.9	67.3	66.8	66.4	65.9	65.4	64.9	64.5	64.0	63.6	63.1	62.7	62.3	61.8	61.4	61.0	60.6	60.2	59.8
21.0	72.5	71.9	71.4	70.9	70.5	70.0	69.5	69.0	68.6	68.1	67.6	67.2	66.8	66.3	65.9	65.5	65.1	64.6	64.2	63.8	63.4	63.0	62.7
22.0	74.9	74.5	74.0	73.5	73.0	72.6	72.1	71.7	71.2	70.8	70.3	69.9	69.5	69.1	68.7	68.2	67.8	67.4	67.1	66.7	66.3	65.9	65.5

Table H-7C: Basic Energy Use (BEU)_- Storage Heat Pump Heater [no interpolation]

Adjusted Recovery Load	Energy Factor																				
	1.8	**1.9**	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**3.0**	**3.1**	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**
6.0	14.1	13.5	13.0	12.6	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.7	9.5	9.2	9.0	8.7	8.5	8.3	8.1	7.9	7.8
6.2	14.4	13.8	13.3	12.8	12.3	11.9	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.3	9.1	8.9	8.7	8.4	8.2	8.0	7.9
6.4	14.7	14.1	13.5	13.0	12.5	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.7	9.5	9.2	9.0	8.8	8.6	8.3	8.2	8.0
6.6	14.9	14.3	13.8	13.2	12.8	12.3	11.9	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.5	8.3	8.1
6.8	15.2	14.6	14.0	13.5	13.0	12.5	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8	8.6	8.4	8.2
7.0	15.5	14.8	14.2	13.7	13.2	12.7	12.3	11.9	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.5	8.3
7.2	15.8	15.1	14.5	13.9	13.4	12.9	12.5	12.1	11.7	11.3	11.0	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8	8.6	8.4
7.4	16.0	15.4	14.7	14.2	13.6	13.1	12.7	12.2	11.8	11.5	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.1	8.9	8.7	8.5
7.6	16.3	15.6	15.0	14.4	13.8	13.3	12.9	12.4	12.0	11.6	11.3	10.9	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8	8.6
7.8	16.6	15.9	15.2	14.6	14.0	13.5	13.0	12.6	12.2	11.8	11.4	11.1	10.8	10.5	10.2	9.9	9.6	9.4	9.2	8.9	8.7
8.0	16.8	16.1	15.4	14.8	14.3	13.7	13.2	12.8	12.4	12.0	11.6	11.2	10.9	10.6	10.3	10.0	9.8	9.5	9.3	9.0	8.8
8.2	17.1	16.4	15.7	15.0	14.5	13.9	13.4	13.0	12.5	12.1	11.7	11.4	11.0	10.7	10.4	10.1	9.9	9.6	9.4	9.2	8.9
8.4	17.4	16.6	15.9	15.3	14.7	14.1	13.6	13.1	12.7	12.3	11.9	11.5	11.2	10.9	10.6	10.3	10.0	9.7	9.5	9.3	9.0
8.6	17.7	16.9	16.1	15.5	14.9	14.3	13.8	13.3	12.9	12.4	12.0	11.7	11.3	11.0	10.7	10.4	10.1	9.9	9.6	9.4	9.1
8.8	17.9	17.1	16.4	15.7	15.1	14.5	14.0	13.5	13.0	12.6	12.2	11.8	11.5	11.1	10.8	10.5	10.2	10.0	9.7	9.5	9.3
9.0	18.2	17.4	16.6	15.9	15.3	14.7	14.2	13.7	13.2	12.8	12.4	12.0	11.6	11.3	11.0	10.7	10.4	10.1	9.8	9.6	9.4
9.2	18.4	17.6	16.8	16.1	15.5	14.9	14.4	13.9	13.4	12.9	12.5	12.1	11.8	11.4	11.1	10.8	10.5	10.2	10.0	9.7	9.5
9.4	18.7	17.9	17.1	16.4	15.7	15.1	14.5	14.0	13.5	13.1	12.7	12.3	11.9	11.5	11.3	10.9	10.6	10.3	10.1	9.8	9.6
9.6	19.0	18.1	17.3	16.6	15.9	15.3	14.7	14.2	13.7	13.3	12.8	12.4	12.0	11.7	11.4	11.0	10.7	10.5	10.2	9.9	9.7
9.8	19.2	18.3	17.5	16.8	16.1	15.5	14.9	14.4	13.9	13.4	13.0	12.6	12.2	11.8	11.5	11.2	10.9	10.6	10.3	10.0	9.8
10.0	19.5	18.6	17.8	17.0	16.3	15.7	15.1	14.6	14.0	13.6	13.1	12.7	12.3	12.0	11.7	11.3	11.0	10.7	10.4	10.1	9.9
10.5	20.1	19.2	18.3	17.6	16.8	16.2	15.6	15.0	14.5	14.0	13.5	13.1	12.7	12.3	11.9	11.6	11.3	11.0	10.7	10.4	10.2
11.0	20.8	19.8	18.9	18.1	17.3	16.7	16.0	15.4	14.9	14.4	13.9	13.4	13.0	12.6	12.3	11.9	11.6	11.3	11.0	10.7	10.4
11.5	21.4	20.4	19.5	18.6	17.8	17.1	16.5	15.9	15.3	14.8	14.3	13.8	13.4	13.0	12.6	12.2	11.9	11.6	11.3	11.0	10.7
12.0	22.1	21.0	20.0	19.1	18.3	17.6	16.9	16.3	15.7	15.1	14.6	14.2	13.7	13.3	12.9	12.5	12.2	11.9	11.5	11.2	11.0
12.5	22.7	21.6	20.6	19.7	18.8	18.1	17.4	16.7	16.1	15.5	15.0	14.5	14.1	13.6	13.2	12.8	12.5	12.1	11.8	11.5	11.2
13.0	23.3	22.2	21.1	20.2	19.3	18.5	17.8	17.1	16.5	15.9	15.4	14.9	14.4	14.0	13.5	13.1	12.8	12.4	12.1	11.8	11.5
13.5	23.9	22.7	21.7	20.7	19.8	19.0	18.2	17.6	16.9	16.3	15.8	15.2	14.7	14.3	13.9	13.5	13.1	12.7	12.4	12.0	11.7
14.0	24.5	23.3	22.2	21.2	20.3	19.5	18.7	18.0	17.3	16.7	16.1	15.6	15.1	14.6	14.2	13.8	13.4	13.0	12.6	12.3	12.0
14.5	25.2	23.9	22.8	21.7	20.8	19.9	19.1	18.4	17.7	17.1	16.5	15.9	15.4	14.9	14.5	14.1	13.7	13.3	12.9	12.6	12.3
15.0	25.8	24.5	23.3	22.2	21.3	20.4	19.6	18.8	18.1	17.4	16.8	16.3	15.8	15.3	14.8	14.4	13.9	13.6	13.2	12.8	12.5
15.5	26.4	25.0	23.8	22.7	21.7	20.8	20.0	19.2	18.5	17.8	17.2	16.6	16.1	15.6	15.1	14.7	14.2	13.8	13.5	13.1	12.8
16.0	27.0	25.6	24.4	23.2	22.2	21.3	20.4	19.6	18.9	18.2	17.6	17.0	16.4	15.9	15.4	15.0	14.5	14.1	13.7	13.4	13.0
16.5	27.6	26.2	24.9	23.7	22.7	21.7	20.8	20.0	19.3	18.6	17.9	17.3	16.7	16.2	15.7	15.2	14.8	14.4	14.0	13.6	13.3
17.0	28.2	26.7	25.4	24.2	23.2	22.2	21.3	20.4	19.7	18.9	18.3	17.7	17.1	16.5	16.0	15.5	15.1	14.7	14.3	13.9	13.5
17.5	28.8	27.3	25.9	24.7	23.6	22.6	21.7	20.8	20.0	19.3	18.6	18.0	17.4	16.8	16.3	15.8	15.4	14.9	14.5	14.1	13.8
18.0	29.4	27.8	26.5	25.2	24.1	23.1	22.1	21.2	20.4	19.7	19.0	18.3	17.7	17.2	16.6	16.1	15.7	15.2	14.8	14.4	14.0
18.5	29.9	28.4	27.0	25.7	24.5	23.5	22.5	21.6	20.8	20.0	19.3	18.7	18.0	17.5	16.9	16.4	15.9	15.5	15.1	14.7	14.3
19.0	30.5	28.9	27.5	26.2	25.0	23.9	23.3	22.0	21.2	20.4	19.7	19.0	18.4	17.8	17.2	16.7	16.2	15.8	15.3	14.9	14.5
19.5	31.1	29.5	28.0	26.7	25.5	24.4	23.3	22.4	21.6	20.8	20.0	19.3	18.7	18.1	17.5	17.0	16.5	16.0	15.6	15.2	14.8
20.0	31.7	30.0	28.5	27.2	25.9	24.8	23.8	22.8	21.9	21.1	20.4	19.7	19.0	18.4	17.8	17.3	16.8	16.3	15.8	15.4	15.0
21.0	32.8	31.1	29.5	28.1	26.8	25.7	24.6	23.6	22.7	21.8	21.1	20.3	19.6	19.0	18.4	17.8	17.3	16.8	16.4	15.9	15.5
22.0	34.0	32.2	30.5	29.1	27.7	26.5	25.4	24.4	23.4	22.5	21.7	21.0	20.3	19.6	19.0	18.4	17.9	17.4	16.9	16.4	16.0

Climate Zone	Factor
1.14	1.04
2, 3	0.99
4, 5, 12	1.07
6-11, 13, 15	0.92
16	1.50

______ Basic Energy Use x ______ CZ Factor = ______ BEU to Line 2a, DHW-1

Instructions: Multiply Basic Energy Use by appropriate Climate Zone Factor from table. **Do not interpolate.**

Table H-7D: Basic Energy Use (BEU) -Instantaneous Gas or Electric Heaters [no interpolation]													
Recovery	**Pilot Energy (Btu/Hour)**												
Energy	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**550**	**600**	**650**	**700**	**750**	**800**
3.0	4.8	5.2	5.6	6.1	6.5	6.9	7.4	7.8	8.3	8.7	9.1	9.6	10.0
3.2	5.0	5.4	5.8	6.3	6.7	7.1	7.6	8.0	8.5	8.9	9.3	9.8	10.2
3.4	5.2	5.6	6.0	6.5	6.9	7.3	7.8	8.2	8.7	9.1	9.5	10.0	10.4
3.6	5.4	5.8	6.2	6.7	7.1	7.5	8.0	8.4	8.9	9.3	9.7	10.2	10.6
3.8	5.6	6.0	6.4	6.9	7.3	7.7	8.2	8.6	9.1	9.5	9.9	10.4	10.8
4.0	5.8	6.2	6.6	7.1	7.5	7.9	8.4	8.8	9.3	9.7	10.1	10.6	11.0
4.2	6.0	6.4	6.8	7.3	7.7	8.1	8.6	9.0	9.5	9.9	10.3	10.8	11.2
4.4	6.2	6.6	7.0	7.5	7.9	8.3	8.8	9.2	9.7	10.1	10.5	11.0	11.4
4.6	6.4	6.8	7.2	7.7	8.1	8.5	9.0	9.4	9.9	10.3	10.7	11.2	11.6
4.8	6.6	7.0	7.4	7.9	8.3	8.7	9.2	9.6	10.1	10.5	10.9	11.4	11.8
5.0	6.8	7.2	7.6	8.1	8.5	8.9	9.4	9.8	10.3	10.7	11.1	11.6	12.0
5.2	7.0	7.4	7.8	8.3	8.7	9.1	9.6	10.0	10.5	10.9	11.3	11.8	12.2
5.4	7.2	7.6	8.0	8.5	8.9	9.3	9.8	10.2	10.7	11.1	11.5	12.0	12.4
5.6	7.4	7.8	8.2	8.7	9.1	9.5	10.0	10.4	10.9	11.3	11.7	12.2	12.6
5.8	7.6	8.0	8.4	8.9	9.3	9.7	10.2	10.6	11.1	11.5	11.9	12.4	12.8
6.0	7.8	8.2	8.6	9.1	9.5	9.9	10.4	10.8	11.3	11.7	12.1	12.6	13.0
6.2	8.0	8.4	8.8	9.3	9.7	10.1	10.6	11.0	11.5	11.9	12.3	12.8	13.2
6.4	8.2	8.6	9.0	9.5	9.9	10.3	10.8	11.2	11.7	12.1	12.5	13.0	13.4
6.6	8.4	8.8	9.2	9.7	10.1	10.5	11.0	11.4	11.9	12.3	12.7	13.2	13.6
6.8	8.6	9.0	9.4	9.9	10.3	10.7	11.2	11.6	12.1	12.5	12.9	13.4	13.8
7.0	8.8	9.2	9.6	10.1	10.5	10.9	11.4	11.8	12.3	12.7	13.1	13.6	14.0
7.2	9.0	9.4	9.8	10.3	10.7	11.1	11.6	12.0	12.5	12.9	13.3	13.8	14.2
7.4	9.2	9.6	10.0	10.5	10.9	11.3	11.8	12.2	12.7	13.1	13.5	14.0	14.4
7.6	9.4	9.8	10.2	10.7	11.1	11.5	12.0	12.4	12.9	13.3	13.7	14.2	14.6
7.8	9.6	10.0	10.4	10.9	11.3	11.7	12.2	12.6	13.1	13.5	13.9	14.4	14.8
8.0	9.8	10.2	10.6	11.1	11.5	11.9	12.4	12.8	13.3	13.7	14.1	14.6	15.0
8.2	10.0	10.4	10.8	11.3	11.7	12.1	12.6	13.0	13.5	13.9	14.3	14.8	15.2
8.4	10.2	10.6	11.0	11.5	11.9	12.3	12.8	13.2	13.7	14.1	14.5	15.0	15.4
8.6	10.4	10.8	11.2	11.7	12.1	12.5	13.0	13.4	13.9	14.3	14.7	15.2	15.6
8.8	10.6	11.0	11.4	11.9	12.3	12.7	13.2	13.6	14.1	14.5	14.9	15.4	15.8
9.0	10.8	11.2	11.6	12.1	12.5	12.9	13.4	13.8	14.3	14.7	15.1	15.6	16.0
9.2	11.0	11.4	11.8	12.3	12.7	13.1	13.6	14.0	14.5	14.9	15.3	15.8	16.2
9.4	11.2	11.6	12.0	12.5	12.9	13.3	13.8	14.2	14.7	15.1	15.5	16.0	16.4
9.6	11.4	11.8	12.2	12.7	13.1	13.5	14.0	14.4	14.9	15.3	15.7	16.2	16.6
9.8	11.6	12.0	12.4	12.9	13.3	13.7	14.2	14.6	15.1	15.5	15.9	16.4	16.8
10.0	11.8	12.2	12.6	13.1	13.5	13.9	14.4	14.8	15.3	15.7	16.1	16.6	17.0
10.2	12.0	12.4	12.8	13.3	13.7	14.1	14.6	15.0	15.5	15.9	16.3	16.8	17.2
10.4	12.2	12.6	13.0	13.5	13.9	14.3	14.8	15.2	15.7	16.1	16.5	17.0	17.4
10.6	12.4	12.8	13.2	13.7	14.1	14.5	15.0	15.4	15.9	16.3	16.7	17.2	17.6
10.8	12.6	13.0	13.4	13.9	14.3	14.7	15.2	15.6	16.1	16.5	16.9	17.4	17.8
11.0	12.8	13.2	13.6	14.1	14.5	14.9	15.4	15.8	16.3	16.7	17.1	17.6	18.0
11.5	13.3	13.7	14.1	14.6	15.0	15.4	15.9	16.3	16.8	17.2	17.6	18.1	18.5
12.0	13.8	14.2	14.6	15.1	15.5	15.9	16.4	16.8	17.3	17.7	18.1	18.6	19.0
12.5	14.3	14.7	15.1	15.6	16.0	16.4	16.9	17.3	17.8	18.2	18.6	19.1	19.5
13.0	14.8	15.2	15.6	16.1	16.5	16.9	17.4	17.8	18.3	18.7	19.1	19.6	20.0
13.5	15.3	15.7	16.1	16.6	17.0	17.4	17.9	18.3	18.8	19.2	19.6	20.1	20.5
14.0	15.8	16.2	16.6	17.1	17.5	17.9	18.4	18.8	19.3	19.7	20.1	20.6	21.0
14.5	16.3	16.7	17.1	17.6	18.0	18.4	18.9	19.3	19.8	20.2	20.6	21.1	21.5
15.0	16.8	17.2	17.6	18.1	18.5	18.9	19.4	19.8	20.3	20.7	21.1	21.6	22.0
15.5	17.3	17.7	18.1	18.6	19.0	19.4	19.9	20.3	20.8	21.2	21.6	22.1	22.5

Table H-7D continued on next page

Table H-7D: Basic Energy Use (BEU) - Instantaneous Gas or Electric Heaters (no interpolation)

Recovery	Pilot Energy (Btu/Hour)												
Energy	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**550**	**600**	**650**	**700**	**750**	**800**
16.0	17.8	18.2	18.6	19.1	19.5	19.9	20.4	20.8	21.3	21.7	22.1	22.6	23.0
16.5	18.3	18.7	19.1	19.6	20.0	20.4	20.9	21.3	21.8	22.2	22.6	23.1	23.5
17.0	18.8	19.2	19.6	20.1	20.5	20.9	21.4	21.8	22.3	22.7	23.1	23.6	24.0
17.5	19.3	19.7	20.1	20.6	21.0	21.4	21.9	22.3	22.8	23.2	23.6	24.1	24.5
18.0	19.8	20.2	20.6	21.1	21.5	21.9	22.4	22.8	23.3	23.7	24.1	24.6	25.0
18.5	20.3	20.7	21.1	21.6	22.0	22.4	22.9	23.3	23.8	24.2	24.6	25.1	25.5
19.0	20.8	21.2	21.6	22.1	22.5	22.9	23.4	23.8	24.3	24.7	25.1	25.6	26.0

Instructions for Instantaneous Gas Water Heaters:

1. Calculate: ________________ / ________________________ = ____________________
   Adjusted Recovery Load (from line 1d, DHW 1) / Recovery Efficiency (fraction) = Recovery Energy

2. Find Basic Energy Use from table using Recovery Energy (Step 1) and Pilot Btu/hr (DHW-1, line F)
   Use nearest table values. At mid-point use higher value. **Do not interpolate.**

3. Enter Basic Energy Use in Line 2a of DHW-1

Instructions for Instantaneous Electric Water Heaters:

1. Calculate: [________________] / ______________________ x 3 = __________________
   Adjusted Recovery Load (from line 1d, DHW-1) / Energy Factor (from line D, DHW-1) x 3 = Basic Energy Use (to line 2a, DHW-1)

2. Enter Basic Energy Use on Line 2a of Worksheet DHW-1.

Note: For instantaneous electric water heaters, Energy Factor equals Recovery Efficiency.

Table H-7E: Jacket Loss (Indirect Gas)

Tank Volume	Storage Tank Insulation R-Value												
(Gallons)	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
0-19	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8
20-29	1.5	1.4	1.3	1.3	1.2	1.2	1.2	1.1	1.0	1.0	1.0	0.9	0.9
30-39	1.7	1.6	1.5	1.4	1.4	1.3	1.3	1.2	1.2	1.1	1.1	1.0	1.0
40-49	1.8	1.7	1.7	1.6	1.5	1.5	1.4	1.3	1.3	1.2	1.1	1.1	1.1
50-59	2.0	1.9	1.8	1.7	1.6	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1
60-69	2.2	2.0	1.9	1.8	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.2	1.2
70-79	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.3
80-89	2.5	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4	1.3
90-99	2.6	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.4
100-119	2.8	2.6	2.5	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4
120-139	3.0	2.8	2.7	2.5	2.4	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.5
140-159	3.3	3.1	2.9	2.7	2.6	2.5	2.4	2.2	2.0	1.9	1.8	1.7	1.6
160-179	3.5	3.3	3.1	2.9	2.7	2.6	2.5	2.3	2.1	2.0	1.9	1.8	1.7
180-199	3.7	3.4	3.2	3.1	2.9	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8
200-249	4.0	3.8	3.5	3.3	3.2	3.0	2.9	2.6	2.4	2.3	2.2	2.0	1.9
250-299	4.5	4.2	3.9	3.7	3.5	3.3	3.2	2.9	2.7	2.5	2.4	2.2	2.1
300-349	4.9	4.6	4.3	4.1	3.8	3.6	3.5	3.2	2.9	2.7	2.6	2.4	2.3
350-399	5.3	5.0	4.7	4.4	4.1	3.9	3.7	3.4	3.2	2.9	2.8	2.6	2.5
400-449	5.7	5.3	5.0	4.7	4.4	4.2	4.0	3.7	3.4	3.1	2.9	2.8	2.6
450-499	6.1	5.7	5.3	5.0	4.7	4.5	4.3	3.9	3.6	3.3	3.1	2.9	2.8
500-1000	8.0	7.4	6.9	6.5	6.1	5.8	5.5	5.0	4.6	4.3	4.0	3.7	3.5
1000	9.5	8.8	8.2	7.7	7.2	6.8	6.5	5.9	5.4	5.0	4.7	4.4	4.1

Instructions:

1. No interpolation allowed.
2. Using total insulation R-value (DHW-3, line 3) and tank volume (DHW-3, line 4), find jacket loss.
3. Enter jacket loss (JL) on line 7, DHW-3.

Table H-8 Active Solar Water Heating Analysis -- Fixed Input Parameters for F-Chart

Input	Name	Value
C9	Incidence Angle Modifier Constant	0.00
C14	Ground Reflectance	0.20
S4	Environment Temperature	70°F
L3	Daily Hot Water Load (gal/day):	
	Single Family	4.74 x (Adjusted Recovery Load from DHW-1 line 1d)
	Multi-Family	4.74 x (Adjusted Recovery Load from DHW-1 line 1d) x (No. of dwelling units from DHW-2 line 1)
L4	Tank Set Temperature	135°F
L5	Water Main Temperature	See Table H-10
S5	Hot Water Auxiliary Tank UA	0.00

Table H-9: Passive Analysis—Insolation Values By Climate Zone

Climate Zone	Insolation
1	1340
2	1658
3	1684
4	1734
5	1753
6	1724
7	1748
8	1768
9	1747
10	1919
11	1706
12	1772
13	1845
14	1988
15	2007
16	1788

Table H-10: Active & Passive Analysis Climate Zone Water Main and Ambient Air Temperatures

Climate Zone	Ambient Air Temp. °F	Water Main Temp. °F
1	52.1	60
2	57.9	65
3	56.9	65
4	59.6	65
5	60.3	65
6	63.5	70
7	62.9	70
8	63.0	70
9	63.6	70
10	63.3	70
11	62.8	65
12	60.3	65
13	62.3	65
14	55.9	65
15	72.6	70
16	42.8	60

Table H-11: Wood Stove Boiler Credit Factors

Climate Zone	Credit Factors With Pump	Credit Factors Without Pump
1	0.225	0.250
2	0.225	0.250
3	0.225	0.250
4	0.135	0.150
5	0.135	0.150
6	0.090	0.100
7	0.090	0.100
8	0.045	0.050
9	0.090	0.100
10	0.045	0.050
11	0.090	0.100
12	0.135	0.150
13	0.090	0.100
14	0.090	0.100
15	0.000	0.000
16	0.270	0.300

H.4 CASE STUDIES

This Part explains how to demonstrate water heating compliance for a number of common and unusual water heating systems.


Examples

Case Studies

Example H-1: Single family residence with one non-recirculating 40-gallon gas water heater.

This qualifies as a standard water heating system and complies automatically. No water heating calculations are required, although they may be performed to take credit for a particularly efficient water heater. See also Part H.6.

Example H-2: Single family residence with one non-recirculating 40-gallon heat pump water heater (EF=1.9) in Climate Zone 12.

Since the minimum EF for a heat pump water heater is 1.8, and this system meets that and all other requirements, it qualifies as a standard water heating system and complies automatically. No water heating calculations are required, although they may be completed at the option of the person submitting compliance documentation. See also Part H.6.

Example H-3: 1,800 ft² single family residence with two identical 30-gallon gas storage tank water heaters and a point of use distribution system.

Water heating calculations are required for this system, including forms DHW-1 and DHW-2A. Form DHW-1 calculates Proposed Energy Use for the single water heater type. Credit for the Point of Use distribution system is also included on Form DHW-1. Form DHW-2A calculates the building's combined Total Proposed Energy Use, and compares it against the building's Standard Energy Use.

Example H-4: 6,000 ft² single family residence with 3 storage gas water heaters (40 gallon, 30 gallon and a 100-gallon unit with 80,000 Btuh input).

Water heating calculations are required for this system, including forms DHW-1, DHW-2A and DHW-3. Form DHW-1 calculates Proposed Energy Use for each individual water heater. Form DHW-3 calculates the Basic Energy Use factor for the 100 gallon water heater because its input is greater than 75,000 Btuh. Form DHW-2A calculates the building's combined Total Proposed Energy Use for the three water heaters, and compares it against the building's Standard Energy Use.

> **NOTE**:
>
> Because the total floor area is greater than 2,500 ft², the Standard Recovery Load and Standard Energy Use for the building from Table H-5 equal that for a 2,500 ft² house.

Example H-5: 2,000 ft² single family residence with one 30-gallon electric water heater and an active solar water heating system.

Water heating calculations are always required for electric water heaters in new buildings. This system requires both forms DHW-1 and DHW-4, including an f-Chart computer analysis to take the energy credit for the active solar water heating system.

> **NOTE**:
>
> For prescriptive compliance with an electric water heater, the solar system is needed to make Proposed Energy Use less than Standard Energy Use for this project.

Example H-6: 10 unit multi-family building with separate gas water heaters for each dwelling unit. Five units have 30-gallon water heaters, and five units have 50-gallon water heaters.

Water heating calculations are not required if each system is non-recirculating because each dwelling unit has a standard water heating system.

Example H-7: 8 unit, 7,800 ft² multi-family building with a 200-gallon storage gas water heater and temperature controlled recirculation system serving all units.

Water heating calculations are required for this system, including forms DHW-1, DHW-2B and DHW-3. See Figures H-3 through H-5 for the completed forms for this example.
In this situation, the correct approach is to use Form DHW-2B to calculate the average size of each dwelling unit within the building and the basic energy use per average unit.

Because a 200 gallon water heater has an input rating over 75,000 Btuh, it is necessary to use Form DHW-3 to calculate its Basic Energy Use for insertion on Line 9 of Form DHW-2B.

DHW-1 compares Proposed Energy Use to Standard Energy Use for the average dwelling unit. The Proposed Energy Use includes a penalty for the recirculation system with temperature controls.

Example H-8: Existing 1,500 ft² single family residence with 500 ft² addition. A new 50-gallon gas storage tank water heater will replace the existing water heating system.

<u>Since this is an alteration to an existing water heating system, no water heating calculations are required. Building energy compliance for the addition may be demonstrated for either</u>

the addition alone or for the existing-plus-addition.

Example H-9: Existing 2,000 ft² single family residence with one 50-gallon gas water heater; a 600 ft² addition with a new instantaneous gas water heater is proposed.

When there is an increase in the number of water heaters with an addition, the standards allow addition alone compliance in certain circumstances. Since this is an instantaneous gas water heater, if it can be demonstrated that it uses no more energy than a 50-gallon gas non-recirculating storage tank (see Chapter 6, Table 6-2), then no water heating calculations are submitted.

Another alternative is to show existing-plus-addition compliance. See Figures H-6 and H-7 for the completed forms for this case.

Default assumptions are used for the existing water heater (see Chapter 6, Table 6-3 for default assumptions). For the existing-plus-addition portion of the analysis, a second Form DHW-1 calculates water heater type, and Form DHW-2A calculates the building's combined Total Proposed Energy Use, and compares it against the whole building's Standard Energy Use.

NOTE:

For instantaneous gas water heaters, Recovery Energy must be calculated using the instructions at the end of Table H-7D before finding Basic Energy Use.

Example H-10: Single family residence with one non-recirculating 50 gallon gas water heater. The water heater has an input rating of 76,000 Btu/hr.

Even though this water heater has an input rating greater than 75,000 Btu/hr, it still qualifies as a standard water heater because it is a storage gas heater of 50 gallons or less. The system still qualifies as a standard water heating system because it meets all of the stated requirements. No water heating calculations are required, and the system complies automatically. See also Part 6.6.

Example H-11: Existing single family residence with one electric water heater; a 500 ft² addition with a 30-gallon electric water heater is proposed.

When there is an increase in the number of water heaters with an addition, the Standards allow addition alone compliance in certain circumstances. If this residence does not have natural gas connected to the building and the new water heater has an EF of 0.90 or greater, the system automatically complies (see Chapter 6, Table 6-2). No water heating calculations are submitted.

Example H-12: A single family residence with one gas water heater is replacing the water heater with a new gas water heater.

This system must comply with the mandatory requirements for alterations. This includes a certified water heater and pipe insulation on the first five feet of hot and cold water pipes. Since compliance with the annual water heating budget is not required, no water heating calculations are required.

Example H-13: A residential building is replacing a gas water heating system with an electric water heating system.

In addition to complying with mandatory requirements mentioned in Example H-12, changing from gas to electric is prohibited (see Chapter 7, Part 7.5) unless it "can be demonstrated that the source energy use of the new system is more efficient than the existing system."

Alterations can also show compliance using an "existing-plus-alteration" compliance approach, as explained in Chapter 7, Part 7.5. This approach could be used to take credit for improvements to the building being made to offset the water heating changes.

WATER HEATING WORKSHEET DHW-1

Multi Family w/ Central System
Project Title

July 20, 1999
Date

No. of Different Water Heater Types: 1 Total No. of Water Heaters: 1 Conditioned Floor Area (CFA): 7800 ft^2

Notes: For single family dwellings with multiple water heaters, also submit DHW-2A. For multi-family buildings, also submit DHW-2B.

Heater Type # 1 Data

A. **Water Heater Type** (check one)
- ✓ Storage Gas
- ___ Large Storage Gas
- ___ Storage Electric
- ___ Storage Heat Pump
- ___ Instantaneous Gas
- ___ Instantaneous Electric
- ___ Indirect Gas

B. **Manufacturer** SOHOT
C. **Model No.** G200
D. **Energy Factor** NA
E. **Gallons** 200
F. **Pilot Btu/hr** NA
G. **Recovery Eff.** 0.78

H. **Auxiliary Input** (check one or both)
- ___ Wood Stove
- ___ Solar, Active or Passive

I. **Distribution System** (check one)
- ___ Standard
- ___ Hot Water Recovery (HWR)
- ___ Point of Use (POU)
- ___ Pipe Insulation (PI)
- ___ Recirculation: No Control
- ___ Recirculation: Timer
- ✓ Recirculation: Temp.
- ___ Recirculation: Time/Temp.
- ___ Recirculation: Demand
- ___ HWR + Recirculation: Demand
- ___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5) 9.5
1b. Distribution Credit/Penalty (from Table 6-6) -0.5
1c. Solar Energy Credit (from DHW-4) 0
1d. Adjusted Recovery Load (1a - 1b - 1c) 10.0
2a. Basic Energy Use (from Table 6-7) 14.3
2b. Wood Stove Boiler Credit (from DHW-4) 0
2c. **Proposed Energy Use** (2a - 2b) 14.3
3. **Standard Energy Use** (from Table 6-5) 21.0

Heater Type #_____ Data

A. **Water Heater Type** (check one)
- ___ Storage Gas
- ___ Large Storage Gas
- ___ Storage Electric
- ___ Storage Heat Pump
- ___ Instantaneous Gas
- ___ Instantaneous Electric
- ___ Indirect Gas

B. **Manufacturer** ________
C. **Model No.** ________
D. **Energy Factor** ________
E. **Gallons** ________
F. **Pilot Btu/hr** ________
G. **Recovery Eff.** ________

H. **Auxiliary Input** (check one or both)
- ___ Wood Stove
- ___ Solar, Active or Passive

I. **Distribution System** (check one)
- ___ Standard
- ___ Hot Water Recovery (HWR)
- ___ Point of Use (POU)
- ___ Pipe Insulation (PI)
- ___ Recirculation: No Control
- ___ Recirculation: Timer
- ___ Recirculation: Temp.
- ___ Recirculation: Time/Temp.
- ___ Recirculation: Demand
- ___ HWR + Recirculation: Demand
- ___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5) ______
1b. Distribution Credit/Penalty (from Table 6-6) ______
1c. Solar Energy Credit (from DHW-4) ______
1d. Adjusted Recovery Load (1a - 1b - 1c) ______
2a. Basic Energy Use (from Table 6-7) ______
2b. Wood Stove Boiler Credit (from DHW-4) ______
2c. **Proposed Energy Use** (2a - 2b) ______
3. **Standard Energy Use** (from Table 6-5) ______

Heater Type #_____ Data

A. **Water Heater Type** (check one)
- ___ Storage Gas
- ___ Large Storage Gas
- ___ Storage Electric
- ___ Storage Heat Pump
- ___ Instantaneous Gas
- ___ Instantaneous Electric
- ___ Indirect Gas

B. **Manufacturer** ________
C. **Model No.** ________
D. **Energy Factor** ________
E. **Gallons** ________
F. **Pilot Btu/hr** ________
G. **Recovery Eff.** ________

H. **Auxiliary Input** (check one or both)
- ___ Wood Stove
- ___ Solar, Active or Passive

I. **Distribution System** (check one)
- ___ Standard
- ___ Hot Water Recovery (HWR)
- ___ Point of Use (POU)
- ___ Pipe Insulation (PI)
- ___ Recirculation: No Control
- ___ Recirculation: Timer
- ___ Recirculation: Temp.
- ___ Recirculation: Time/Temp.
- ___ Recirculation: Demand
- ___ HWR + Recirculation: Demand
- ___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5) ______
1b. Distribution Credit/Penalty (from Table 6-6) ______
1c. Solar Energy Credit (from DHW-4) ______
1d. Adjusted Recovery Load (1a - 1b - 1c) ______
2a. Basic Energy Use (from Table 6-7) ______
2b. Wood Stove Boiler Credit (from DHW-4) ______
2c. **Proposed Energy Use** (2a - 2b) ______
3. **Standard Energy Use** (from Table 6-5) ______

4. **For Prescriptive Compliance** (one water heater per dwelling): Line 2c must not exceed Line 3 for Heater Type #1.

Figure H-3: Example H-7 DHW-1 Form
Multi-Family with Central System

Multi Family w/ Central System — Project Title

July 20, 1999 — Date

Notes: In addition to this form, a DHW-1 Water Heating Worksheet must also be submitted to document water heating type(s). If the calculation (line 4) is by "Individual Dwelling Unit" and system configuration (line 5) is "Individual Heaters," no additional information need be entered on this sheet.

Multi-Family Project Data

1. Number of dwelling units: 8
2. Total conditioned floor area: 7800 ft^2
3. Average floor area: 975 (Line 2/Line 1)
4. Calculation by (check one): ✓ Average Dwelling Unit; ___ Individual Dwelling Unit
5. System configuration (check one): ___ Individual Heaters (one per dwelling unit); ✓ Shared Heaters (multiple dwelling units per heater)

Analysis by Average Dwelling Unit

	No. of Heaters	Heater Type#	Manufacturer and Model#	One Individual Heater Per Dwelling Unit: Gallons Each	Gallons Total	Energy Factor Each	Energy Factor Total
6a =	1	#1	SOHOT G200				
6b =		#2					
6c =		#3					
Total	___ = 7a				Total ___ = 7b		Total ___ = 7c
					Ave. ___ = 8a (7b÷7a)		Ave. ___ = 8b (7c÷7a)

Individual Heaters

9a. Enter value 8a on DHW-1 Line E.

10a. Enter value 8b on DHW-1 Line D.

11a. Check compliance on DHW-1 for average dwelling unit and average water heating.

Shared Heater(s)

9b. Average unit Adjusted Recovery Load: 10.0 From DHW-1, Line 1d

10b. Total Adjusted Recovery Load: 80.0 (Line 1) × (Line 9b)

11b. Total Basic Energy Use: 114.74 From Table 6-7, or DHW-3

12b. Average Unit Basic Energy Use: 14.34 (Line 11b) ÷ (Line 1): enter on Line 2a, DHW-1

13b. Check average unit compliance on DHW-1.

Compliance

14. **Prescriptive Compliance** (for individual or shared heaters):
DHW-1 Line 2c must be equal to or less than DHW-1 Line 3.
See Part 6.1 and Chapter 3 in the *Residential Manual* for details.

Figure H-4: Example H-7 DHW-2B Form / Multi-Family with Central System

Multi Family w/ Central System	July 20, 1999
Project Title	Date

Note: This sheet must also be submitted with a DHW-1 water heating worksheet, as well as a DHW-2B form with large storage gas heaters in multi-family buildings.

Indirect Gas Water Heaters

1. Storage tank Manufacturer/Model No. ____________________
2. Boiler Manufacturer/Model No. ____________________
3. Storage tank insulation R-value: Tank _______ External _______ Total _______
4. Storage tank volume (gallons) _______
5. Boiler AFUE or Instantaneous Water Heater Recovery Efficiency EFF _______
6. Adjusted Recovery Load (MBtu/yr, from Line 1d, DHW-1) ARL _______
7. Jacket loss (MBtu/yr, from Table 6-7E) JL _______
8. Pilot Energy (Btuh, from appliance database, or use 800) PE _______
9. Basic Energy Use (BEU) = (ARL + JL) ÷ (0.98 × EFF) + (PE × 0.0088) BEU _______
   (Enter BEU on DHW-1, Line 2a or on DHW-2B, Line 11b)

Large Storage Gas Heaters (> 75,000 Btuh input)

1. Water Heater Manufacturer SOHOT
2. Water Heater Model No. G200
3. Storage Tank Insulation R-Value: Tank 12 External _______ Total 12
4. Storage Tank Volume (gallons) 200
5. Water Heater Recovery Efficiency (decimal fraction) EFF 0.78
6. Adjusted Recovery Load (Mbtu/yr, from Line 1d, DHW-1 or Line 10b, DHW-2B) ARL 80
7. Jacket Loss (Mbtu/yr, from Table 6-7E) JL 3.8
8. Standby Loss % (from appliance database - e.g., “2.7”) SBL% 2.5
9. Basic Energy Use (BEU) = [ARL + (JL × SBL)] ÷ EFF BEU 114.74
   (Enter BEU on DHW-1, Line 2a or on DHW-2B, Line 11b)

Figure H-5: Example H-7 DHW-3 Form / Multi-Family with Central System

Jones Residence: Existing Plus Addition — Project Title

July 1, 1999 — Date

No. of Different Water Heater Types: 2   Total No. of Water Heaters: 2   Conditioned Floor Area (CFA): 2600 ft²

Notes: For single family dwellings with multiple water heaters, also submit DHW-2A. For multi-family buildings, also submit DHW-2B.

Heater Type # 1 Data

A. **Water Heater Type** (check one)
- ✓ Storage Gas
- ___ Large Storage Gas
- ___ Storage Electric
- ___ Storage Heat Pump
- ___ Instantaneous Gas
- ___ Instantaneous Electric
- ___ Indirect Gas

B. **Manufacturer** SOHOT
C. **Model No.** G40
D. **Energy Factor** 0.60
E. **Gallons** NA
F. **Pilot Btu/hr** NA
G. **Recovery Eff.** 0

H. **Auxiliary Input** (check one or both)
- ___ Wood Stove
- ___ Solar, Active or Passive

I. **Distribution System** (check one)
- ✓ Standard
- ___ Hot Water Recovery (HWR)
- ___ Point of Use (POU)
- ___ Pipe Insulation (PI)
- ___ Recirculation: No Control
- ___ Recirculation: Timer
- ___ Recirculation: Temp.
- ___ Recirculation: Time/Temp.
- ___ Recirculation: Demand
- ___ HWR + Recirculation: Demand
- ___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5)	7.8
1b. Distribution Credit/Penalty (from Table 6-6)	0
1c. Solar Energy Credit (from DHW-4)	0
1d. Adjusted Recovery Load (1a - 1b - 1c)	7.8
2a. Basic Energy Use (from Table 6-7)	15.7
2b. Wood Stove Boiler Credit (from DHW-4)	0
2c. **Proposed Energy Use** (2a - 2b)	15.7
3. **Standard Energy Use** (from Table 6-5)	NA

For Prescriptive Compliance (one water heater per dwelling): Line 2c must not exceed Line 3 for Heater Type #1.

Heater Type # 2 Data

A. **Water Heater Type** (check one)
- ___ Storage Gas
- ___ Large Storage Gas
- ___ Storage Electric
- ___ Storage Heat Pump
- ✓ Instantaneous Gas
- ___ Instantaneous Electric
- ___ Indirect Gas

B. **Manufacturer** GTHERM
C. **Model No.** I00
D. **Energy Factor** NA
E. **Gallons** NA
F. **Pilot Btu/hr** 300
G. **Recovery Eff.** 0.80

H. **Auxiliary Input** (check one or both)
- ___ Wood Stove
- ___ Solar, Active or Passive

I. **Distribution System** (check one)
- ✓ Standard
- ___ Hot Water Recovery (HWR)
- ___ Point of Use (POU)
- ___ Pipe Insulation (PI)
- ___ Recirculation: No Control
- ___ Recirculation: Timer
- ___ Recirculation: Temp.
- ___ Recirculation: Time/Temp.
- ___ Recirculation: Demand
- ___ HWR + Recirculation: Demand
- ___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5)	7.8
1b. Distribution Credit/Penalty (from Table 6-6)	0
1c. Solar Energy Credit (from DHW-4)	0
1d. Adjusted Recovery Load (1a - 1b - 1c)	12.4
2a. Basic Energy Use (from Table 6-7)	0
2b. Wood Stove Boiler Credit (from DHW-4)	0
2c. **Proposed Energy Use** (2a - 2b)	12.4
3. **Standard Energy Use** (from Table 6-5)	NA

Figure H-6: Example H-9 DHW-1 for Existing + Addition
Existing + Addition Analysis

Heater Type #_____ Data

A. **Water Heater Type** (check one)
- ___ Storage Gas
- ___ Large Storage Gas
- ___ Storage Electric
- ___ Storage Heat Pump
- ___ Instantaneous Gas
- ___ Instantaneous Electric
- ___ Indirect Gas

B. **Manufacturer** ______
C. **Model No.** ______
D. **Energy Factor** ______
E. **Gallons** ______
F. **Pilot Btu/hr** ______
G. **Recovery Eff.** ______

H. **Auxiliary Input** (check one or both)
- ___ Wood Stove
- ___ Solar, Active or Passive

I. **Distribution System** (check one)
- ___ Standard
- ___ Hot Water Recovery (HWR)
- ___ Point of Use (POU)
- ___ Pipe Insulation (PI)
- ___ Recirculation: No Control
- ___ Recirculation: Timer
- ___ Recirculation: Temp.
- ___ Recirculation: Time/Temp.
- ___ Recirculation: Demand
- ___ HWR + Recirculation: Demand
- ___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5)	
1b. Distribution Credit/Penalty (from Table 6-6)	
1c. Solar Energy Credit (from DHW-4)	
1d. Adjusted Recovery Load (1a - 1b - 1c)	
2a. Basic Energy Use (from Table 6-7)	
2b. Wood Stove Boiler Credit (from DHW-4)	
2c. **Proposed Energy Use** (2a - 2b)	
3. **Standard Energy Use** (from Table 6-5)	

Jones Residence: Existing Plus Addition — Project Title

July 1, — Date

Note: In addition to this form, a DHW-1 Water Heating Worksheet must also be submitted to document water heater type(s).

Single Family Project Data

1. No. of different water heater types: 2
2. Total conditioned floor area: 2600 ft^2

	No. of Heaters	Heater Type #	Manufacturer & Model No.
3a.	1	#1	SOHOT G40
3b.	1	#2	GTHERM I00
3c.		#3	

4. 2 Total Number of Water Heaters
5. Standard Recovery Load: 15.6 from Table 6-5 based on line 2
6. Recovery Load Per Heater: 7.8 (line 5 ÷ line 4); enter on DHW-1, line 1a for each Heater Type, and complete calculation through line 2c.
7. Proposed Energy Use, Heater Type #1: 15.7 (from DHW-1 line 2c, Type #1) × (line 3a)
8. Proposed Energy Use, Heater Type #2: 12.4 (from DHW-1 line 2c, Type #2) × (line 3b)
9. Proposed Energy Use, Heater Type #3: NA (from DHW-1 line 2c, Type #3) × (line 3c)
10. Total Proposed Energy Use: 28.1 (line 7 + line 8 + line 9)
11. Standard Energy Use: 28.5 from Table 6-5 based on line 2

Compliance

12. **Prescriptive Compliance:** Line 10 must be equal to or less than line 11. See Part 6.1 and Chapter 3 in the *Residential Manual* for details.

Figure H-7: Example H-9 DHW-2A for Existing + Addition Existing + Addition Analysis

H.5 COMBINED HYDRONIC SPACE AND WATER HEATING

Compliance/
Plan Check

Combined Hydronic

Chapter 7, Part 7.9 explains hydronic space heating systems. When such a system serves the additional function of providing domestic hot water, the system is analyzed for its water heating performance as if the space heating function were separate. In other words, treat any hydronic system used for water heating the same as any other water heating system: Input the correct water heater type, auxiliary input credit (if any) and specify the distribution system on DHW-1.

The DHW-5 is used to calculate an effective AFUE or to adjust the AFUE for pipe losses when a space heating boiler is also used for water heating (see Part H.3).

Complete the DHW-5 worksheet for any project that includes a hydronic space heating system, combined hydronic space and water heating system, or boiler (see Part H.3). This worksheet should accompany all necessary water heating compliance worksheets. The DHW-5 worksheet is used to determine the Effective AFUE for storage gas water heaters and the Effective HSPF for storage electric and heat pump water heaters used to supply energy for the combined hydronic space and water heating system.

For performance compliance, the water heating worksheets are not printed, but the inputs will appear on the C-2R and CF-1R forms.

H.6 SYSTEM DESCRIPTIONS

Construction

System Types and Installation Criteria

The water heating calculation method evaluates water heating systems by analyzing the following system components: Water Heaters, Auxiliary Systems and Distribution Systems. Separate calculations are required for Hydronic Space and Water Heating Systems. This part describes all of the system types that fall within each category, and explains installation criteria.

WATER HEATERS

This part describes water heater types which can be analyzed using the water heating method:

- Standard Water Heater
- Storage Gas
- Large Storage Gas
- Storage Electric
- Storage Heat Pump
- Instantaneous Gas
- Instantaneous Electric
- Indirect Gas

All water heaters must be certified (see Chapter 1, Part 1.6). This guarantees that they meet the minimum requirements of the National Efficiency Standards and State Efficiency Standards as described in the California Appliance Efficiency Regulations.

For small storage gas water heaters this corresponds to an Energy Factor = 0.62 - (0.0019 x Volume).

For small storage electric water heaters the minimum is an Energy Factor = 0.93 - (0.00132 x Volume).

Standard Water Heater

A standard water heater is one that automatically complies with the standards, since its characteristics meet the installation criteria described below. For a system in a single-family dwelling consisting of a single standard water heater and a standard distribution system, compliance is demonstrated by listing water heater type and distribution system on form CF-1R. No other water heating calculations are required.

Installation Criteria:

One gas water heater of 50 gallons capacity or less per dwelling unit. On any unit with an EF of less than 0.58, R-12 external insulation is mandatory.

Storage Gas

A gas water heater designed to heat and store water at less than 180 °F. Water temperature is controlled with a thermostat. Storage gas water heaters have a manufacturer's specified storage capacity of at least two gallons and less than 75,000 Btuh input.

Large Storage Gas

A storage gas water heater with greater than 75,000 Btuh input.

Storage Electric

An electric water heater designed to heat and store water at less than 180 °F. Water temperature is controlled with a thermostat. Storage electric water heaters have a manufacturer's specified storage capacity of at least two gallons.

Storage Heat Pump

An electric water heater that uses a compressor to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water. It includes all necessary auxiliary equipment such as fans, storage tanks, pumps or controls. EFs for heat pump water heaters are found in the Commission's *Directory of Certified Water Heaters*.

Instantaneous Gas

A gas water heater controlled manually or automatically by a water flow activated control or a combination of water flow and thermostatic controls, with a manufacturer's specified storage capacity of less than two gallons.

Recovery efficiency and pilot energy are in the Commission's database of certified water heaters.

Instantaneous Electric

An electric water heater controlled automatically by a thermostat, with a manufacturer's specified storage capacity of less than two gallons.

NOTE:
Instantaneous water heaters are not generally designed for use with solar water heating systems or as heat sources for indirect fired water heaters. They are also typically inappropriate for use with recirculation systems. Consult manufacturer's literature when considering these applications.

Indirect Gas

A water heater consisting of a storage tank with no heating elements or combustion devices, connected via piping and recirculating pump to a heat source consisting of a gas or oil fired boiler, or instantaneous gas water heater (see note following the definitions of Instantaneous Gas and Electric).

Installation Criteria:

The storage tank must be insulated in accordance with Section 150(j) 1.B. of the standards, which requires a factory-installed minimum of R-16 (labeled on outside of tank) or a minimum of R-12 external insulation (see Chapter 2, Part 2.4).

The piping connecting the heating source and the storage tank must be insulated to R-4 for pipe less than or equal to 2 inches in diameter and to R-6 for pipes larger than 2 inches in diameter. This includes any piping located in concrete slabs or underground.

External Tank Insulation

Insulation applied to the exterior of storage type water heater tanks.

When installed, water heater insulation should be applied to completely cover the exterior sides of water heaters, but should not conceal controls or access ports to burners, cover combustion air openings, or interfere in any way with safe water heater operation. Insulation of top and bottom surfaces is not necessary.

External tank insulation is mandatory for water heaters with less than 0.58 EF, and for unfired water heater tanks that do not have R-16 internal insulation (as indicated on the outside of the tank).

AUXILIARY SYSTEMS

Auxiliary systems add hot water to the overall water heating system through means other than the typical water heaters defined above.

The Water Heating Calculation Method allows water heating credits for three auxiliary systems, which save energy by using nondepletable resources as energy sources. These systems – Passive and Active Solar Water Heaters and Wood Stove Boilers – are described below.

Passive Solar Water Heaters

Systems, which collect and store solar thermal energy for domestic water heating applications and do not require electrical energy input for recirculating water through a solar collector.

Installation Criteria:

Passive solar water heaters must be tested in accordance with Solar Rating & Certification Corporation (SRCC) Standard 200-82, except as noted below.

Thermosyphon solar water heaters employing flat plate collectors comply with test requirements if collectors are tested in accordance with SRCC Standard 100-81.

SRCC's address is:

Solar Rating & Certification Corporation
122 "C" Street NW. 4th Floor
Washington, DC 20001-2109

Active Solar Water Heaters

Systems, which collect and store solar thermal energy for domestic water heating applications requiring electrical energy input for operation of pumps or other components.

Installation Criteria:

Flat plate collectors used with active solar waters must be tested in accordance with SRCC Standard 100-81 (see address above).

Wood Stove Boilers

Wood stoves equipped with heat exchangers for heating domestic hot water (see Figure H-8).

Installation Criteria:

Energy credits may only be taken when the building department having jurisdiction has determined that natural gas is not available.

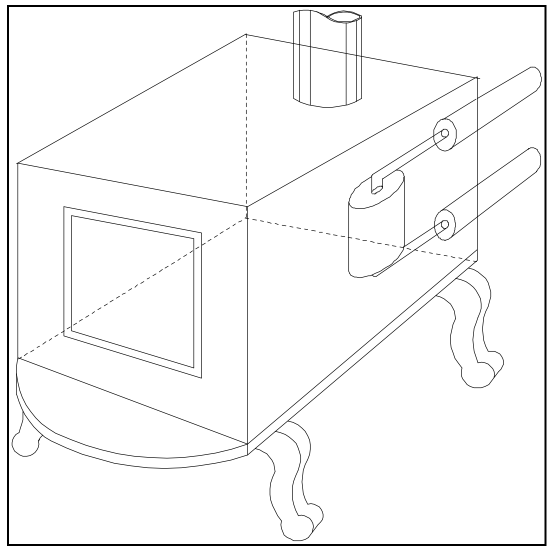


Figure H-8: Wood Stove Boiler

A tempering valve must be installed at the outlet of the water heater to prevent scalding.

A pressure-temperature relief valve must be installed at the wood stove.
The wood stove boiler must be properly sized to minimize the amount of excess hot water produced by the unit.

All health and safety codes, including codes applying to pressurized boiler vessels, must be met.

DISTRIBUTION SYSTEMS

The water heating distribution system is the configuration of piping, pumps and controls that regulates delivery of hot water from the water heater to all end uses within the building.

All criteria listed below are based on Commission contract #400-88-003, *Residential Water Heating Study*: March 31, 1991.

The water heating calculation method gives credits for especially energy-efficient distribution systems, while taking penalties for less energy-efficient systems (see Table H-6). The distribution systems that may be analyzed are:

- Standard Distribution System
- Point of Use
- Hot Water Recovery
- Pipe Insulation
- Recirculation: Continuous
- Recirculation: Temperature Controlled
- Recirculation: Time Controlled
- Recirculation: Time & Temperature Controlled
- Recirculation: Demand Pumping
- Hot Water Recovery + Recirculation: Demand Pumping
- Pipe Insulation + Recirculation: Demand Pumping

Only one distribution system type may be chosen for each water heating system, with the exception of recirculation systems with demand pumping which may be combined with ***either*** *hot water recovery systems* ***or*** *pipe insulation.* In either of these cases the two appropriate adjustment values from Table H-6 are added together and input as Distribution Credit on form DHW-1.

Pipe insulation is required for all other recirculation systems (except Demand) and may not be used for extra credit (see Chapter 2, Part 2.4).

Standard Distribution System

A standard distribution system does not incorporate a pump for recirculation of hot water, and does not take credit for any design features eligible for energy credits. A distribution system normally eligible for energy credits, such as one with pipe insulation, may be modeled as standard (i.e., no credits) to avoid the need for any water heating calculations.

Compliance for any water heating system in a single family house with standard distribution and only one standard water heater is demonstrated by listing the water heater type and distribution system on form CF-1R. No other water heating forms are required.

Installation Criteria:

No pumps may be used to recirculate hot water. The first five feet of hot and cold water piping adjacent to the water heater must be insulated with minimum R-4 insulation (see Chapter 2, Part 2.4).

Point of Use

A distribution piping system that limits hot water distribution system heat loss by minimizing the distance between the water heater and hot water fixtures.

Credit for only one Point of Use may be taken even if additional water heaters meeting the criteria will be installed.

Installation Criteria:

The distance between the water heater and any hot water fixture cannot exceed eight feet, measured in plan view (see Figure H-9).

All water heaters and hot water fixtures must be shown on plans submitted for local building department plan check.

EXCEPTION: Washing machines for clothing may be located more than eight feet from the water heater.

Hot Water Recovery System

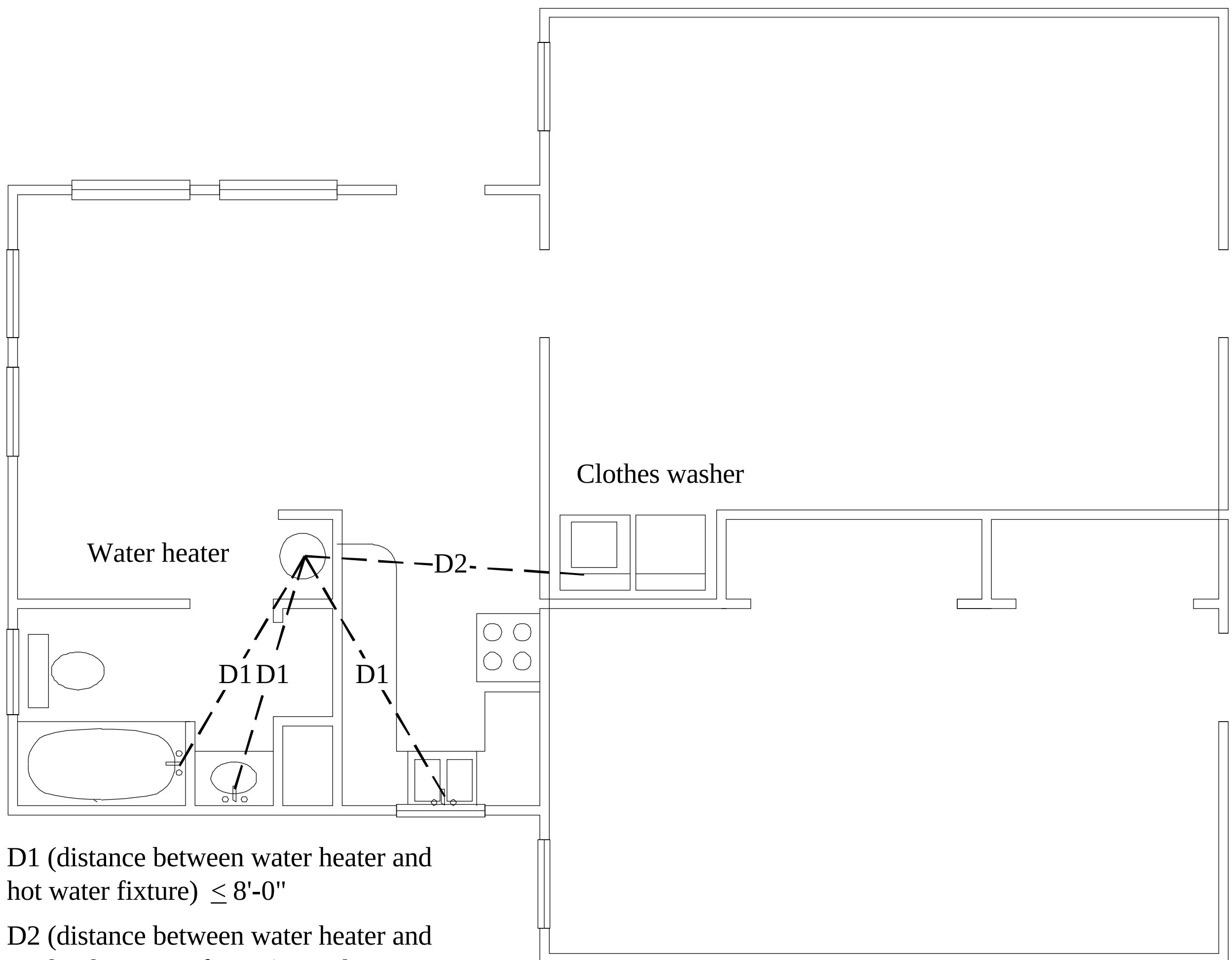
A distribution system that includes a device that reclaims hot water from the distribution piping by drawing it back to the water heater or other insulated storage vessel.

Installation Criteria:

Hot water recovery systems (HWR) must be plumbed such that a positive supply of cold water from the water supply main is provided to the appropriate connection on the device.

Hot water recovery systems must be connected to each water heater serving individual dwelling units.

Credit for only one HWR may be taken even though more than one may be installed or specified in the building plans.



D1 (distance between water heater and hot water fixture) ≤ 8'-0"

D2 (distance between water heater and washer hot water fixture) may be ≥ 8'-0"

Figure H-9: Point of Use

Credit may not be taken for a HWR in a multi-family central water heating system serving multiple dwelling units.

Hot water recovery systems may be used for credit in recirculation systems with demand pumping.

Pipe Insulation

Table H-6 lists credits that may be taken for insulation of water mains in addition to insulation required by Section 150 of the Standards (first five feet from water heater). The pipe insulation credit is only allowed for 3/4 inch or larger, non-recirculating hot water mains and Demand Recirculating Systems.

Installation Criteria:

R-value of applied insulation must not be less than R-4.0, or less than R-6.0 for pipe diameters greater than 2 inches. No additional credit may be taken for R-4 or R-6 insulation, respectively (see Part 2.3).

Pipe insulation may only be used for credit in recirculation systems with demand pump. *Pipe insulation is required for all other recirculation systems and is not eligible for credit.*

> **NOTE**:
> Heat tape – electric resistance heating tape wrapped around hot water pipes – may be used only for freeze protection and cannot be used instead of mandatory pipe insulation (see Chapter 2, Part 2.3) or pipe insulation receiving distribution credit.

Recirculation System

Continuous distribution system using a pump to recirculate hot water to branch piping though a looped hot water main with no control of the pump, such that water flow is continuous.

Installation Criteria:

All piping used to recirculate hot water must be insulated with R-4 insulation or equivalent. This includes any recirculating piping located in concrete slabs or underground. Since the standards require this insulation, it is not eligible for the Pipe Insulation credit.

Recirculation System: Temperature Controlled

Recirculation system that uses temperature controls to cycle pump operation to maintain circulated water temperatures within certain limits.

Installation Criteria:

All criteria listed for continuous recirculation systems apply.

An automatic thermostatic control must be installed to cycle the pump on and off in response to the temperature of water returning to the water heater through the recirculation piping. Minimum differential or "deadband" of the control shall not be less than 20°F.

Plans must indicate pump and control manufacturer, model number and temperature settings.

Recirculation System: Time Controlled

Recirculation system that uses a timer control to cycle pump operation based on time of day.

Installation Criteria:

All criteria listed for continuous recirculation systems apply.

A timer must be permanently installed to regulate pump operation. Timer setting must permit the pump to be cycled off for at least eight hours per day.

Plans must indicate pump and timer manufacturer and model number.

Recirculation System: Time and Temperature Controlled

Recirculation system that uses both temperature and timer controls to regulate pump operation.

Installation Criteria:

All criteria listed for continuous, temperature controlled and timer controlled recirculation systems apply.

Recirculation System: Demand Pumping

Recirculation system that uses brief pump operation to recirculate hot water to fixtures on demand.

Installation Criteria:

All criteria listed for continuous recirculation systems apply, except that pipe insulation is not required.

Pump start-up must be provided by one or more momentary contact switches, or a hot water flow sensing device located at the water heater. Systems using momentary contact switches must have at least one switch at each floor level, one of, which must be located at the kitchen sink.

Pump shut-off must be provided by either a temperature sensing device that shuts off the pump when the pipe is full of hot water, or by a timer which limits pump run time to two minutes or less.

Plans must include a wiring/circuit diagram, and manufacturer/model numbers for the pump and timer/temperature sensing device.

Demand systems can only be used for control of pumps serving one dwelling unit. They are not used for central systems in multi-family buildings.

NOTE:

In an exception to the rule that distribution systems may not be combined, insulation ***or*** hot water recovery systems may be used for credit in recirculation systems with demand pumping (see below). Pipe insulation is required for all other recirculation systems, so it is not eligible for extra credit.

NOTE:

Recirculation systems are not used with instantaneous water heaters.

Hot Water Recovery + Recirculation System: Demand Pumping

This combination system receives both credits explained under each system, separately, above. Installation criteria for both credits – hot water recovery and demand recirculation – apply to this combined distribution type.

Pipe Insulation + Recirculation System: Demand Pumping

This combination system receives both credits explained under each system, separately, above. Installation criteria for both credits – pipe insulation and demand recirculation – apply to this combined distribution type.

Hydronic Space and Water Heating

Combined Hydronic Space and Water Heating

A combined water and space heating system using the same water heater to heat the building and to provide domestic hot water.

Installation Criteria:

Piping for pump recirculating hydronic space heating supply lines must be insulated to R-4 for pipes less than or equal to 2 inches nominal diameter and R-6 for larger pipe diameters.

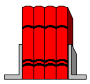
Dedicated (Separate) Hydronic Space Heating

A system using separate water heaters to provide space heating and domestic hot water, each dedicated to one function.

Installation Criteria:

Piping for pump recirculating hydronic space heating supply lines must be insulated to R-4.0 for pipes 2 inches or less in diameter and to R-6.0 for larger pipe diameters. See the standards, Section 105(j).

H.7 LIGHTING



Energy Code

Kitchen Lighting (Section 150(k)1, 3)

1. *Luminaires for general lighting in kitchens shall have lamps with an efficacy of not less than 40 lumens per watt. General lighting must provide a sufficient light level for basic kitchen tasks and provide a uniform pattern of illumination. A luminaire(s) that is(are) the only lighting in a kitchen will be considered general lighting. General lighting shall be controlled by a switch on a readily accessible lighting control panel at an entrance to the kitchen.*

   Additional luminaires to be used only for specific decorative effects need not meet this requirement.

3. *Luminaires installed to meet the 40 lumens per watt requirements of Section 150(k) 1. or 2. shall not contain medium base incandescent lamp sockets, and shall be on separate switches from any incandescent lighting.*

Construction

Kitchen Lighting

Installing energy-efficient lamps and fixtures can reduce lighting energy costs without sacrificing the quality or quantity of light available. As indicated in Table 2-2, a 40-watt standard fluorescent lamp is over four times as efficient as a 100-watt standard incandescent lamp.

The general lighting in kitchens must:

- Have an efficacy of *at least 40 lumens/watt* (see Table 2-2).
- Provide a uniform pattern of lighting, such as a fixture in the center of the kitchen or around the perimeter (not a fixture in the corner).
- Provide a light level sufficient for performing basic kitchen tasks such as preparing meals and washing dishes.
- Be controlled on a readily accessible switch at an entrance to the kitchen (not in a cupboard or beside the kitchen sink).
- Be switched independent of incandescent lighting.
- Shall not contain medium-base incandescent lamp sockets. This prevents the occupant from replacing the efficient light source with an incandescent bulb.

If there is only one light in the kitchen, it is general lighting.

Additional luminaires for decorative effect do not need to meet these requirements

Incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (IC-rated) in compliance with Section 150(k)4 (see below).

Inspection

Kitchen Lighting

The lighting in the kitchen, either general or the only lighting, must:

- Be fluorescent or another product that has at least 40 lumens/watt (see Table 2-2).
- Provide a uniform pattern of lighting, such as a fixture in the center of the kitchen or around the perimeter (not a fixture in the corner).
- Provide a light level sufficient for performing basic kitchen tasks such as preparing meals and washing dishes.
- Be controlled on a readily accessible switch at an entrance to the kitchen (not in a cupboard or beside the kitchen sink).
- Be switched separately from incandescent lighting and on a control panel at an entrance to the kitchen.
- Not contain medium-base incandescent lamp sockets. This prevents the occupant

from replacing the efficient light source with an incandescent bulb.

Table H-2. Typical Efficacy of Luminaries

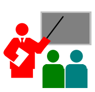
Light Source	Type	Rated Lamp Watts	Typical Efficacy Lumens/Watt[1]
Incandescent	Standard	40 - 100	14 - 18
Incandescent	Halogen	40 - 250	20[2]
Incandescent	Halogen IR	See footnote [3]	Up to 30
Fluorescent (Lamp/Ballast Systems)[4]	Full-Size, 4' Long	32 - 40	69 - 91
	U-Shaped T-8 Bipin	16 - 31	78 - 90
	Compact Fluorescent	5 - 9	26 - 38
	Compact Fluorescent	13 +	42 - 58
Metal Halide	Metal Halide	32 - 175	50 - 90
High Pressure Sodium	White High Pressure Sodium	35 - 100	36 - 55

1 Includes power consumed by ballasts where applicable.

2 Halogen capsule incandescent lamps may be the most efficient light source for highlighting applications. Most halogen lamps are designed to produce a beam of directed light. Manufacturer's data typically list the "candlepower" intensity of that beam, rather than lumens (lumens measure total light output in all directions).

3 A new technology using infrared reflecting films on the halogen capsules has increased output up to 30 lumens/watt for some high wattage lamps.

4 Efficacy of fluorescent lighting varies depending on lamp and ballast types.



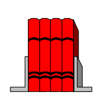
Kitchen Lighting

Would one fluorescent light in a kitchen, installed over the sink or under one cabinet, meet the "general lighting" requirements?

No. The general lighting must evenly light the entire kitchen. Two *examples* of acceptable lighting configurations are (1) fluorescent lighting (or other light source with at least 40-lumens/watt) around the perimeter of the kitchen (under or over cabinets), or (2) a fluorescent in the center of the kitchen.

If a customer asks me not to install fluorescent lights in their home, are there any other light sources I can use to meet the kitchen lighting requirements?

Yes, although they may not be readily available, there are products other than fluorescent which meet the lighting requirements of the standards, Section 150(k). The two criteria for the kitchen and bathroom general lighting are (1) a lamp with an efficacy of 40 lumens/watt or more, and (2) the fixtures cannot contain a medium base incandescent lamp socket. Table 2-2 indicates the typical lumens/watt of several common products, some of which meet the required lumens/watt. Specifications from a product's manufacturer can also be used to verify that a product has at least 40 lumens/watt.



Energy Code

Bathroom Lighting (Section 150(k)2 - 3)

2. *Each room containing a shower or bathtub shall have at least one luminaire with lamp(s) with an efficacy of 40 lumens per watt or greater. If there is more than one luminaire in the room, the high efficacy luminaire shall be switched at an entrance to the room.*

ALTERNATIVE to Section 150(k)2.: A high efficacy luminaire need not be installed in a bathroom if:

A. A luminaire with lamps with an efficacy of 40 lumens per watt or greater is installed in a utility room, laundry room, or garage; and

B. All luminaires permanently mounted to the residence providing outdoor lighting shall be installed with the following characteristics:

(1) Luminaires with lamps with 40 lumens per watt or greater; or

(2) Luminaires with lamps with an efficacy of less than 40 lumens per watt shall be equipped with a motion sensor.

Note: When using this alternative for multiple bathrooms, after complying with B. for the first bathroom, each additional bathroom in which a high efficacy luminaire is not installed must comply with A. alone.

3. *Luminaires installed to meet the 40 lumens per watt requirements of Section 150(k) 1. or 2. shall not contain medium base incandescent lamp sockets, and shall be on separate switches from any incandescent lighting.*

Construction

Bathroom Lighting

Each room with a shower or bathtub must have at least one luminaire with lamps with an efficacy of at least 40 lumens/watt.

If there is more than one luminaire in the room, the high-efficacy luminaire must be switched at an entrance to the room.

As an alternative, both of the following are required:

1. A luminaire with 40 lumens/watt lamps must be installed in another room with utilitarian functions such as a laundry room, utility room or garage; and
2. All permanently mounted outside lighting must either be at least 40 lumens/watt or equipped with a motion sensor.

When using this alternative for two or more rooms with showers or bathtubs, compliance with item 1. above is sufficient for the second or third rooms since the outside lighting is already in compliance with item 2 above.

Luminaires installed to meet the 40 lumens/watt requirements cannot contain medium base incandescent lamp sockets, and must be on separate switches from incandescent lighting.

Incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (IC-rated) in compliance with Section 150(k)4 (see below).

Installing energy-efficient lamps and fixtures can reduce lighting energy costs without sacrificing the quality or quantity of light available. As indicated in Table 2-2, a 40 watt standard fluorescent lamp is over four times as efficient as a 100 watt standard incandescent lamp.

Inspection

Bathroom Lighting

Each room with a shower or bathtub (no requirement in a half-bath) must have at least one luminaire with lamps with an efficacy of at least 40 lumens/watt, which may be fluorescent or another efficient technology (see Table 2-2 above).

When there is more than one luminaire in the room, the high-efficacy luminaire (greater than or equal to 40 lumens/watt) must be switched at an entrance to the room.

As an alternative, both of the following are required:

1. A luminaire with 40 lumens/watt lamps must be installed in a laundry room, utility room or garage; and
2. All permanently mounted outside lighting must either be at least 40 lumens/watt or equipped with a motion sensor.

Luminaires installed to meet the 40 lumens/watt requirements cannot contain medium base incandescent lamp sockets, and must be on separate switches from incandescent lighting.

Incandescent lighting fixtures recessed into insulated ceilings must be IC-rated in compliance with Section 150(k)4 (see below).

Examples

Bathroom Lighting

If a customer asks me not to install fluorescent lights in their home, are there any other light sources I can use to meet the bathroom and kitchen lighting requirements?

Yes, although they may not be readily available, there are products other than fluorescent which meet the lighting requirements of the standards, Section 150(k). The two criteria for the kitchen and bathroom general lighting are (1) a lamp with an efficacy of 40 lumens/watt or more, and (2) the fixtures cannot contain a medium base incandescent lamp socket. Table 2-2 indicates the typical lumens/watt of several common products, some of which meet the required lumens/watt. Specifications from a product's manufacturer can also be used to verify that a product has at least 40 lumens/watt.

Energy Code

Recessed Lighting (Section 150(k)4)

All incandescent lighting fixtures recessed into insulated ceilings shall be approved for zero-clearance insulation cover (I.C.) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials.

Construction

Recessed Lighting

All incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (IC-rated) in compliance with Section 150(k)4.

Although this requirement does not apply to fluorescent fixtures, recessed lighting fixtures left uninsulated significantly increase the heat loss through the roof/ceiling area reducing the effectiveness of the insulation.

Heat lamps are not required to be IC-rated.

Examples

Recessed Lighting

I'd like to know if it is possible to use non-IC rated incandescent fixtures recessed in an insulated ceiling. Although I've never been able to find a bulb heater (heat lamp) that is IC-rated [approved for insulation cover], they are very popular with my customers. Can I use this product?

It is possible to build a box of gypsum board or wire mesh over the fixture in the attic, which can then be insulated. By separating the insulation from the fixture, the fixture is not recessed into the insulated ceiling. As long as there is sufficient clearance between the fixture and the insulation to prevent a fire hazard, this assembly is acceptable for meeting Section 150(k)4 of the standards.

Note: Recessed fluorescent fixtures do not need to be IC-rated.

If insulation is installed between floors of an apartment building (sound-proofing), can I install incandescent fixtures that are not IC-rated?

No. Although this isn't part of the building envelope, standards Section 150(k) states that any incandescent fixtures recessed into an insulated ceiling must be approved for zero-clearance insulation cover.

WATER HEATING WORKSHEET DHW-1

____ ____________________
Project Title Date

No. of Different Water Heater Types: _____ Total No. of Water Heaters: _____ Conditioned Floor Area (CFA): _____ft^2

Notes: For single family dwellings with multiple water heaters, also submit DHW-2A. For multi-family buildings, also submit DHW-2B.

Heater Type #_____ Data

A. **Water Heater Type** (check one)
___ Storage Gas
___ Large Storage Gas
___ Storage Electric
___ Storage Heat Pump
___ Instantaneous Gas
___ Instantaneous Electric
___ Indirect Gas

B. **Manufacturer** _______________
C. **Model No.** _______________
D. **Energy Factor** __________
E. **Gallons** __________
F. **Pilot Btu/hr** __________
G. **Recovery Eff.** __________

H. **Auxiliary Input** (check one or both)
___ Wood Stove
___ Solar, Active or Passive

I. **Distribution System** (check one)
___ Standard
___ Hot Water Recovery (HWR)
___ Point of Use (POU)
___ Pipe Insulation (PI)
___ Recirculation: No Control
___ Recirculation: Timer
___ Recirculation: Temp.
___ Recirculation: Time/Temp.
___ Recirculation: Demand
___ HWR + Recirculation: Demand
___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5) ______
1b. Distribution Credit/Penalty (from Table 6-6) ______
1c. Solar Energy Credit (from DHW-4) ______
1d. Adjusted Recovery Load (1a - 1b - 1c) ______
2a. Basic Energy Use (from Table 6-7) ______
2b. Wood Stove Boiler Credit (from DHW-4) ______
2c. **Proposed Energy Use** (2a - 2b) [ ]
3. **Standard Energy Use** (from Table 6-5) [ ]

Heater Type #_____ Data

A. **Water Heater Type** (check one)
___ Storage Gas
___ Large Storage Gas
___ Storage Electric
___ Storage Heat Pump
___ Instantaneous Gas
___ Instantaneous Electric
___ Indirect Gas

B. **Manufacturer** _______________
C. **Model No.** _______________
D. **Energy Factor** __________
E. **Gallons** __________
F. **Pilot Btu/hr** __________
G. **Recovery Eff.** __________

H. **Auxiliary Input** (check one or both)
___ Wood Stove
___ Solar, Active or Passive

I. **Distribution System** (check one)
___ Standard
___ Hot Water Recovery (HWR)
___ Point of Use (POU)
___ Pipe Insulation (PI)
___ Recirculation: No Control
___ Recirculation: Timer
___ Recirculation: Temp.
___ Recirculation: Time/Temp.
___ Recirculation: Demand
___ HWR + Recirculation: Demand
___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5) ______
1b. Distribution Credit/Penalty (from Table 6-6) ______
1c. Solar Energy Credit (from DHW-4) ______
1d. Adjusted Recovery Load (1a - 1b - 1c) ______
2a. Basic Energy Use (from Table 6-7) ______
2b. Wood Stove Boiler Credit (from DHW-4) ______
2c. **Proposed Energy Use** (2a - 2b) [ ]
3. **Standard Energy Use** (from Table 6-5) [ ]

Heater Type #_____ Data

A. **Water Heater Type** (check one)
___ Storage Gas
___ Large Storage Gas
___ Storage Electric
___ Storage Heat Pump
___ Instantaneous Gas
___ Instantaneous Electric
___ Indirect Gas

B. **Manufacturer** _______________
C. **Model No.** _______________
D. **Energy Factor** __________
E. **Gallons** __________
F. **Pilot Btu/hr** __________
G. **Recovery Eff.** __________

H. **Auxiliary Input** (check one or both)
___ Wood Stove
___ Solar, Active or Passive

I. **Distribution System** (check one)
___ Standard
___ Hot Water Recovery (HWR)
___ Point of Use (POU)
___ Pipe Insulation (PI)
___ Recirculation: No Control
___ Recirculation: Timer
___ Recirculation: Temp.
___ Recirculation: Time/Temp.
___ Recirculation: Demand
___ HWR + Recirculation: Demand
___ PI + Recirculation: Demand

Energy Use Calculation

1a. Standard Recovery Load (from Table 6-5) ______
1b. Distribution Credit/Penalty (from Table 6-6) ______
1c. Solar Energy Credit (from DHW-4) ______
1d. Adjusted Recovery Load (1a - 1b - 1c) ______
2a. Basic Energy Use (from Table 6-7) ______
2b. Wood Stove Boiler Credit (from DHW-4) ______
2c. **Proposed Energy Use** (2a - 2b) [ ]
3. **Standard Energy Use** (from Table 6-5) [ ]

4.**For Prescriptive Compliance** (one water heater per dwelling): Line 2c must not exceed Line 3 for Heater Type #1.

SINGLE FAMILY W/ MULTIPLE WATER HEATERS DHW-2A

Project Title ______________________ Date ______________

Note: In addition to this form, a DHW-1 Water Heating Worksheet must also be submitted to document water heater type(s).

Single Family Project Data

1. No. of different water heater types: _______

2. Total conditioned floor area: _______ ft^2

	No. of Heaters	Heater Type #	Manufacturer & Model No.
3a.	______	#1	
3b.	______	#2	
3c.	______	#3	

4. ______ Total Number of Water Heaters

5. Standard Recovery Load: _______ from Table 6-5 based on line 2

6. Recovery Load Per Heater: _______ (line 5 ÷ line 4); enter on DHW-1, line 1a for each Heater Type, and complete calculation through line 2c.

7. Proposed Energy Use, Heater Type #1: _______ (from DHW-1 line 2c, Type #1) × (line 3a)

8. Proposed Energy Use, Heater Type #2: _______ (from DHW-1 line 2c, Type #2) × (line 3b)

9. Proposed Energy Use, Heater Type #3: _______ (from DHW-1 line 2c, Type #3) × (line 3c)

10. Total Proposed Energy Use: _______ (line 7 + line 8 + line 9)

11. Standard Energy Use: _______ from Table 6-5 based on line 2

Compliance

12. **Prescriptive Compliance:** Line 10 must be equal to or less than line 11.
See Part 6.1 and Chapter 3 in the *Residential Manual* for details.

WATER HEATING FOR MULTI-FAMILY BUILDINGS DHW-2B

Project Title ______________________ Date ______________

Notes: In addition to this form, a DHW-1 Water Heating Worksheet must also be submitted to document water heating type(s). If the calculation (line 4) is by "Individual Dwelling Unit" and system configuration (line 5) is "Individual Heaters," no additional information need be entered on this sheet.

Multi-Family Project Data

1. Number of dwelling units: ________
2. Total conditioned floor area: ________ ft^2
3. Average floor area: ________ (Line 2/Line 1)
4. Calculation by (check one): ___ Average Dwelling Unit
   ___ Individual Dwelling Unit
5. System configuration (check one): ___ Individual Heaters (one per dwelling unit)
   ___ Shared Heaters (multiple dwelling units per heater)

Analysis by Average Dwelling Unit

	No. of Heaters	Heater Type#	Manufacturer and Model#	One Individual Heater Per Dwelling Unit: Gallons Each	Gallons Total	Energy Factor Each	Energy Factor Total
6a =	______	#1	______________	______	______	______	______
6b =	______	#2	______________	______	______	______	______
6c =	______	#3	______________	______	______	______	______
Total	______ = 7a			Total	______ = 7b	Total	______ = 7c
				Ave.	______ = 8a (7b÷7a)	Ave.	______ = 8b (7c÷7a)

Individual Heaters

9a. Enter value 8a on DHW-1 Line E.

10a. Enter value 8b on DHW-1 Line D.

11a. Check compliance on DHW-1 for average dwelling unit and average water heating.

Shared Heater(s)

9b. Average unit Adjusted Recovery Load: ___________ From DHW-1, Line 1d

10b. Total Adjusted Recovery Load: ___________ (Line 1) × (Line 9b)

11b. Total Basic Energy Use: ___________ From Table 6-7, or DHW-3

12b. Average Unit Basic Energy Use: ___________ (Line 11b) ÷ (Line 1): enter on Line 2a, DHW-1

13b. Check average unit compliance on DHW-1.

Compliance

14. **Prescriptive Compliance** (for individual or shared heaters):
DHW-1 Line 2c must be equal to or less than DHW-1 Line 3.
See Part 6.1 and Chapter 3 in the *Residential Manual* for details.

INDIRECT & LARGE STORAGE GAS WATER HEATERS DHW-3

Project Title ________________ Date ________________

Note: This sheet must also be submitted with a DHW-1 water heating worksheet, as well as a DHW-2B form with large storage gas heaters in multi-family buildings.

Indirect Gas Water Heaters

1. Storage tank Manufacturer/Model No. ____________________
2. Boiler Manufacturer/Model No. ____________________
3. Storage tank insulation R-value: Tank _______ External _______ Total _______
4. Storage tank volume (gallons) _______
5. Boiler AFUE or Instantaneous Water Heater Recovery Efficiency EFF _______
6. Adjusted Recovery Load (MBtu/yr, from Line 1d, DHW-1) ARL _______
7. Jacket loss (MBtu/yr, from Table 6-7E) JL _______
8. Pilot Energy (Btuh, from appliance database, or use 800) PE _______
9. Basic Energy Use (BEU) = (ARL + JL) ÷ (0.98 × EFF) + (PE × 0.0088) BEU _______
   (Enter BEU on DHW-1, Line 2a or on DHW-2B, Line 11b)

Large Storage Gas Heaters (> 75,000 Btuh input)

1. Water Heater Manufacturer ____________________
2. Water Heater Model No. ____________________
3. Storage Tank Insulation R-Value: Tank _______ External _______ Total _______
4. Storage Tank Volume (gallons) _______
5. Water Heater Recovery Efficiency (decimal fraction) EFF _______
6. Adjusted Recovery Load (Mbtu/yr, from Line 1d, DHW-1 or Line 10b, DHW-2B) ARL _______
7. Jacket Loss (Mbtu/yr, from Table 6-7E) JL _______
8. Standby Loss % (from appliance database - e.g., “2.7”) SBL% _______
9. Basic Energy Use (BEU) = [ARL + (JL × SBL)] ÷ EFF BEU _______
   (Enter BEU on DHW-1, Line 2a or on DHW-2B, Line 11b)

AUXILIARY INPUTS (SOLAR AND WOOD BOILERS) (Part 1 of 2) DHW-4

______________________________ ______________
Project Title Date

Notes: This sheet must also be submitted with a DHW-1 water heating worksheet. Detailed instructions for calculating Active Solar Credit, Passive Solar Credit or Wood Stove Boiler Credit are contained in Section 6.3 of the *Residential Manual*.

Active Solar Credit

1. Solar Energy Credit =
(Solar Fraction) × (line 1a - line 1b, from DHW-1) × (0.80) = _______

Active Solar Credit Notes: In equation 1, Solar Fraction = "FDHW" from F-Chart. F-Chart parameters are fixed as listed in Table 6-8. Enter Line 1 on DHW-1, Line 1c.

Passive Solar Credit

2. Calculate temperature difference from SRCC data:

T_{SRCC} = $[Q_{SAV}$ /(100 gal/day x 8.25 Btu/gal-°F)] + $[Q_{CAP}$ /(V_t x 8.25 Btu/gal-°F)] = ________

Where: Q_{SAV} (Btu/day) = from SRCC test results
Q_{CAP} (Btu) = from SRCC test results
V_t (gal) = total volume of solar storage tank

3. Calculate energy losses during SRCC test:

$Q_{LOSS,SRCC}$ = T_{SRCC} x 16 hr/day x L Btu/hr-°F = ________

Where: 16 = number of hours system is losing heat
L (Heat Loss Coefficient, Btu/hr-°F from SRCC test results)

4. Calculate energy collected during the SRCC test:

$Q_{TOTAL,SRCC} = Q_{SAV} + Q_{LOSS,SRCC}$ = ________

5. Adjust energy collected to climate zone insolation values (see Table 6-9)

$Q_{TOTAL,LOCAL}$ = 1204 + [($Q_{TOTAL,SRCC}$ - 1204)/1500] x CZ insolation = ________

6. Determine $T_{TANK,LOCAL}$, average tank temperature delivered to the site:

$T_{TANK,LOCAL} = (A_1 + A_2 + Q_{TOTAL,LOCAL}) / (A_3 + A_4)$ = ________

Where: A_1 = (50 gal/day) x (8.25 Btu/gal-°F) x (CZ Water Main Temp)
A_2 = 16 hrs/day x L x (CZ Ambient Air Temp)
A_3 = (50 gal/day) x (8.25 Btu/gal-°F)
A_4 = 16 hrs/day x L
CZ Water Main Temp and CZ Ambient Air Temp from Table 6-10

7. Determine energy losses at the site:

$Q_{LOSS, LOCAL}$ = L x 16 hrs x ($T_{TANK, LOCAL}$ - CZ Ambient Air Temp) = ________

Project Title ______________________ Date ______________

Notes: This sheet must also be submitted with a DHW-1 water heating worksheet. Detailed instructions for calculating Active Solar Credit, Passive Solar Credit or Wood Stove Boiler Credit are contained in Section 6.3 of the *Residential Manual*.

Passive Solar Credit (cont.)

8. Determine energy used by electric resistance freeze protection devices:

   ERP = (Freeze days/yr + 4) x (Collector Area) x (0.5 kBtu /ft^2 -freeze day) = ________

   This is calculated only if the system uses electric resistance freeze protection.

9. Calculate system total annual energy contribution (mmBtu/yr); Enter on DHW-1, Line 1c:

   $\{(Q_{TOTAL, LOCAL} - Q_{LOSS, LOCAL}) \times 0.365 - ERP\} \times 0.001 \times$ (No. of Dwelling Units) = ________

The credit calculated cannot exceed DHW-1, Line 1a - Line 1b - 3 mmBtu/yr.

Wood Stove Boiler Credit

10. Wood Stove Boiler Credit:
    (Basic Energy Use) DHW-1, Line 2a × (Credit Factor) From Table 6-12 = ________

Table 1: Energy Used by Freeze Protection Devices

Climate Zone	Freeze Degree Hours[1]	Climate Zone	Freeze Degree Hours[1]
1	44	9	1
2	624	10	57
3	3	11	417
4	157	12	324
5	74	13	195
6	0	14	2813
7	0	15	28
8	1	16	8152-26153[2]

1. Freeze Degree Hours is defined as the annual sum-mation of hours that dry bulb temperature is less than or equal to 34° F from midnight to 10 am and from 6 pm to midnight.
2. The lower limit is for Mt. Shasta (3535' elevation) and the upper limit is for Tahoe City (6,230' elevation).

NOTE: Data in this table is used in item 8 of DWH-4 (Part 2 of 2).

Project Title ______________________ Date ______________

Storage Gas

1. Recovery Efficiency/AFUE	_____	unitless	From manufacturer's literature or appliance database
2. Average Hourly Pipe Heat Loss	_____	kBtu/hr	From Pipe Heat Loss Worksheet below
3. Rated Input	_____	kBtu/hr	From manufacturer's literature or appliance database
4. Effective AFUE	_____	unitless	Line 1 - (Line 2 ÷ Line 3)

Storage Electric

1. Average Hourly Pipe Heat Loss	_____	kBtu/hr	From Pipe Heat Loss Worksheet below
2. Rated Input	_____	kW	From manufacturer's literature or appliance database
3. Pump Watts	_____	watt	From manufacturers literature
4. Term A	_____	unitless	1 - [Line 1 ÷ (3.413 × Line 2)]
5. Term B	_____	unitless	1 + [Line 3 ÷ (1000 × Line2)]
6. Effective HSPF (no fan)	_____	Btu/watt	3.413 × (Line 4 ÷ Line 5)
7. Effective HSPF (with fan)	_____	Btu/watt	1.017 ÷ [(1 ÷ Line 6) + 0.005]

Heat Pump

1. Energy Factor	_____	unitless	From manufacturer's literature or appliance database
2. Average Hourly Pipe Heat Loss	_____	kBtu/hr	From Pipe Heat Loss Worksheet below
3. Rated Input	_____	kW	From manufacturer's literature or appliance database
4. Recovery Efficiency	_____	unitless	1 ÷ [(1 ÷ Line 1) - 0.1175]
5. Climate Zone Adjustment	_____	unitless	From table below
6. Effective HSPF (no fan)	_____	Btu/watt	3.413 × [(Line 4 ÷ Line 5) - Line 2 ÷ (3.413 × Line 3)]
7. Effective HSPF (with fan)	_____	Btu/watt	1.017 ÷ [(1 ÷ Line 6) + 0.005]

Climate Zone Adjustment

Climate Zone	Adjustment
1, 14	1.04
2, 3	0.99
4, 5, 12	1.07
6-11, 13, 15	0.92
16	1.50

Pipe Heat Loss Rate Table

Pipe Nominal Diameter (inches)	Insulation Thickness (inches) 0.5	0.75	1.0
0.50	71.6	60.9	54.2
0.75	91.1	75.8	66.6
1.00	109.9	90.1	78.8
1.50	146.7	117.5	100.3
2.00	182.9	144.3	121.7

Pipe Heat Loss Worksheet

(Complete this section when more than 10 feet of pipe is in unconditioned space.)

Description of Pipe Size and Insulation Condition	Pipe Heat Loss Rate (kBtu/yr•ft)[1]		Pipe Length (ft)		Total Pipe Heat Loss			Average Hourly Pipe Heat Loss (kBtu/hr)
________	______	×	______	=	______			
________	______	×	______	=	______			
________	______	×	______	=	______			
________	______	×	______	=	______			
________	______	×	______	=	______			
			Sum	=	______	÷	8760 =	______

[1] From Pipe Heat Loss Rate Table.

I: Plan Check Guides and Inspection Checklists

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-1: CERTIFICATE OF COMPLIANCE(part 1 of 2)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
GENERAL		
	DATE: Verify version of Energy Efficiency Standards that apply	2.1.1 Table 1-1
GENERAL INFORMATION		
	BUILDING CONDITIONED FLOOR AREA	2.1.2 3.3.1A
	CLIMATE ZONE	APPENDIX C 3.3.1A
	BUILDING TYPE: Verify Occupancy Group(s) and if Residential determine whether NonRes or Res Standards apply.	2.1.1A 2.1.2B 3.3.1A
	PHASE OF CONSTRUCTION	
	NEW CONSTRUCTION	2.2.2 3.3.1A
	ADDITION	2.2.5 3.3.1A
	ALTERATION	2.2.4 3.3.1A
	UNCONDITIONED	2.2.1 3.3.1A
	METHOD OF ENVELOPE COMPLIANCE	
	COMPONENT	3.2.2 3.1.1A
	OVERALL ENVELOPE	3.2.3 3.1.1A
	PERFORMANCE	3.2.4 3.1.1B 3.3.1A
STATEMENT OF COMPLIANCE		
	CIVIL ENGINEER, MECHANICAL ENGINEER, ELECTRICAL ENGINEER, OR ARCHITECT.	3.3.1
	CONTRACTOR DESIGNING WORK CONTRACTED TO PERFORM	
	OTHERWISE EXEMPT: APPLICANT TO STATE REASON FOR EXEMPTION	
ENVELOPE MANDATORY MEASURES		
	INDICATE LOCATION ON PLANS OF NOTE BLOCK FOR MANDATORY MEASURES.	3.2.1 3.3.1A
	DOORS, WINDOWS, SKYLIGHT	3.2.1A 3.3.1A
	JOINTS AND OPENINGS	3.2.1B 3.3.1A
	INSULATION MATERIALS	3.2.1C 3.3.1A
	DEMISING WALL INSULATION	3.2.1D 3.3.1A

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-1: CERTIFICATE OF COMPLIANCE(part 2 of 2)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OPAQUE SURFACES		
	SURFACE TYPE (Name to match Opaque Surfaces on attached forms)	3.3.1B
	CONSTRUCTION TYPE	3.3.1B
	LOCATION/COMMENTS	3.3.1B
	AREA	3.3.1B
	U-VAL	3.3.1B
	AZM	3.3.1B
	TILT	3.3.1B
	SOLAR GAINS	3.3.1B
	FORM 3 REFERENCE	3.3.1B
	LOCATION/COMMENTS	3.3.1B
FENESTRATION SURFACES		
	COMPONENT (Name to match Windows on attached forms. See definition of SLOPE in Section 3.1.2A	3.1.2B
	FRAME TYPE	3.1.2B
	EXTERIOR SHADE?	3.1.2B
	OVERHANG CREDIT	3.1.2B
	GLAZING TYPE	3.1.2B
EXTERIOR SHADING		
	FENESTRATION #	3.3.1B
	EXTERIOR TYPE	3.3.1B
	SHGC	3.3.1B
	WINDOWS	3.3.1B
	Hgt.	3.3.1B
	Width	3.3.1B
	OVERHANG	3.3.1B
	Len.	3.3.1B
	Hgt.	3.3.1B
	LExt.	3.3.1B
	RExt	3.3.1B
	LEFT FIN	3.3.1B
	Dist.	3.3.1B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-1: CERTIFICATE OF COMPLIANCE(PART 2 OF 2) (CONT.)

CATEGORY	**CONSERVATION MEASURE**	***REFERENCE***
	Len.	3.3.1B
	Hgt.	3.3.1B
	RIGHT FIN	3.3.1B
	Dist.	3.3.1B
	Len.	3.3.1B
	Hgt.	3.3.1B
	NOTES TO FIELD	3.3.1B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: ENVELOPE COMPONENT METHOD

Note: There are two (2) methods of prescriptive compliance for the envelope requirements; the Envelope Component Method and the Overall Envelope Method. For a brief description of each of these methods refer to Section 3.1.1 A. Understanding of the "Surface Definitions" is necessary to proceed with plan checking; Refer to Section 3.1.2 A.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
WINDOW AREA CALCULATION SKYLIGHT AREA CALCULATION		
	GROSS WALL AREA(GWA) (Note: The sum of the window area, door area, and exterior wall area.)	3.1.2A 3.3.2A
	DISPLAY PERIMETER(DP)(See Definition Display Perimeter)	3.3.2A
	MAXIMUM ALLOWABLE WINDOW AREA	3.2.2E 3.3.2A
	PROPOSED WINDOW AREA(See Definition Window Area)	3.1.2A 3.3.2A
	ATRIUM HEIGHT(See Definition Atrium)	3.1.2A 3.2.2F 3.3.2B
	Allowed %	3.2.2F 3.3.2B
	GR. ROOF AREA(See Definition Gross Exterior Roof Area) (Note: The sum of the Skylight area and the exterior roof/ceiling)	3.1.2A 3.3.2B
	ALLOW. SKY. AREA	3.2.2F 3.3.2B
	ACTUAL SKY. AREA(See Definition Skylight)	3.1.2A 3.3.2B
OPAQUE SURFACES		
	ASSEMBLY NAME	ENV-1 3.3.4A 3.3.6A 3.3.2C
	TYPE	3.2.2A 3.3.3B 3.2.2C 3.2.2D
	HEAT CAPACITY > or =7.0	3.2.2B APP A:FORM ENV-3 3.2.2C
	INSULATION R-VALUE	
	WALL, FLOOR, SOFFIT WITH HC <7.0 AND ALL ROOF/CEILING	3.2.2A 3.2.2B 3.2.2C 3.2.2D
	PROPOSED(See Definition Insulation R-Value)	
	MIN. ALLOWED	
	Nonresidential Buildings	Standards Table 1-H
	High-rise Residential Bldgs and Guest Rms of Hotel/Motel Bldgs.	Standards Table 1-I
	ASSEMBLY U-VALUE	
	PROPOSED	APPENDIX A:FORM ENV-3
	WOOD FRAME	3.1.2D
	METAL FRAME	3.1.2E
	MASONRY	3.1.2F
	TABLE VALUES? (if no, form ENV-3 is required)	APPENDIX B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: ENVELOPE COMPONENT METHOD

Note: There are two (2) methods of prescriptive compliance for the envelope requirements; the Envelope Component Method and the Overall Envelope Method. For a brief description of each of these methods refer to Section 3.1.1 A. Understanding of the "Surface Definitions" is necessary to proceed with plan checking; Refer to Section 3.1.2 A.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OPAQUE SURFACES		
	MAX ALLOWED	
	Nonresidential Buildings	Standards Table 1-H
	High-rise Residential Bldgs and Guest Rms of Hotel/Motel Bldgs.	Standards Table 1-I

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: ENVELOPE COMPONENT METHOD

Note: There are two (2) methods of prescriptive compliance for the envelope requirements; the Envelope Component Method and the Overall Envelope Method. For a brief description of each of these methods refer to Section 3.1.1 A. Understanding of the "Surface Definitions" is necessary to proceed with plan checking; Refer to Section 3.1.2 A.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
WINDOWS		
	WINDOW NAME From ENV-1	
	ORIENTATION See Definition Orientation	3.1.2A 3.3.2D
	U-VALUE	3.1.2H 3.3.2D
	PROPOSED (RSHG)	3.2.2E 3.3.2D
	ALLOWED RSHG	3.2.2E 3.3.2D
	# OF PANES	3.3.2D
	OVERHANG	3.1.2J 3.3.2D
	PROPOSED RSHG	3.1.2J 3.3.2D
	Nonresidential Buildings	Standards Table 1-H
	High-rise Residential Bldgs and Guest Rooms of Hotel/Motel Bldgs.	Standards Table 1-I
	ALLOW. RSHG	3.3.2d
SKYLIGHTS		
	SKYLIGHT NAME From ENV-1	
	GLAZING	3.2.2F 3.3.2E
	Translucent	Table 3-20 3.3.2E
	Transparent	Table 3-20 3.3.2E
	NO. OF PANES	3.3.2E 3.3.2e
	U-VALUE	3.1.2H 3.3.2E
	PROPOSED	3.1.2H 3.3.2E
	ALLOWED	3.2.2F 3.3.2E
	Nonresidential Buildings	Standards Table 1-H
	High-rise Residential Bldgs and Guest Rooms of Hotel/Motel Bldgs.	Standards Table 1-I
	SOLAR HEAT GAIN COEFFICIENT	3.3.2E
	PROPOSED	3.1.2J 3.3.2E
	ALLOWED	3.3.2E
	Nonresidential Buildings	Standards Table 1-H

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: ENVELOPE COMPONENT METHOD(CONT.)

Note: There are two (2) methods of prescriptive compliance for the envelope requirements; the Envelope Component Method and the Overall Envelope Method. For a brief description of each of these methods refer to Section 3.1.1 A. Understanding of the "Surface Definitions" is necessary to proceed with plan checking; Refer to Section 3.1.2 A.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
SKYLIGHTS		
	High-rise Residential Bldgs and Guest Rooms of Hotel/Motel Bldgs.	Standards Table 1-I

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 1 OF 5

Note: There are two (2) methods of prescriptive compliance for the envelope requirements; the Envelope Component Method and the Overall Envelope Method. For a brief description of each of these methods refer to Section 3.1.1 A. Understanding of the "Surface Definitions" is necessary to proceed with plan checking; Refer to Section 3.1.2 A.

This calculation is performed to determine if a Window Adjustment Factor or Skylight Adjustment Factor is necessary. If they are found not to be necessary Part 4 of 5 will not be submitted.

Test: If the proposed window area is greater than the larger of the Display Perimeter or 40% of the GROSS exterior wall area:

WINDOW ADJUSTMENT FACTOR = MAXIMUM AREA / PROPOSED AREA

Test: If the proposed window area is less than 10% of the GROSS exterior wall area:

WINDOW ADJUSTMENT FACTOR = MINIMUM AREA / PROPOSED AREA

Test: If the proposed skylight area is greater than the allowed skylight area:

SKYLIGHT ADJUSTMENT FACTOR = ALLOWED SKYLIGHT AREA / PROPOSED

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
WINDOW AREA TEST		
	DISPLAY PERIMETER (DP) See Definition Display Perimeter.	3.1.2A 3.3.3A
	GROSS EXTERIOR WALL AREA See Definition Gross Exterior Wall Area (Note: The sum of the window area, door area, exterior wall area, and roof / ceiling area)	3.1.2A 3.3.3A
	PROPOSED WINDOW AREA	3.3.3A
SKYLIGHT AREA TEST		
	ATRIUM HEIGHT See Definition Atrium	3.1.2A
	STANDARD %	3.3.3A
	GROSS ROOF AREA See definition Gross Exterior Roof Area. (Note: The sum of Skylight and Roof / Ceiling Area.)	3.1.2A 3.3.3A
	STANDARD SKYLIGHT AREA	3.3.3A
	PROPOSED SKYLIGHT AREA	3.3.3A

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 2 OF 5

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT LOSS		
	WALLS	
	PROPOSED ASSEMBLY NAME	From ENV-1 3.3.3B
	PROPOSED AREA See definition Exterior Wall Area(Area of opaque exterior surface of exterior walls. Does not include windows or doors.)	3.1.2A 3.3.3B
	PROPOSED HEAT CAPACITY	3.3.3B 3.1.2H
	PROPOSED U-VALUE	3..1.2C FORM ENV-3 3.3.3B
	WOOD FRAME	3.1.2D 3.3.3B
	METAL FRAME	3.1.2E 3.3.3B
	MASONRY	3.1.2F 3.3.3B
	TABLE VALUES	3.3.3B
	PROPOSED UA	3.2.3A 3.3.3B
	STANDARD AREA (ADJUSTED) If window Adjustment Factor is required from column G, Part 5 of 5.	3.1.2A 3.2.3A 3.3.3B
	STANDARD U-VALUE: Nonresidential Buildings	Standards Table 1-H
	STANDARD U-VALUE: High-rise Residential Bldgs and Guest rooms of Hotel / Motel Bldgs.	Standards Table 1-I
	STANDARD UA	3.2.3B 3.3.3B
	ROOFS / CEILINGS	
	PROPOSED ASSEMBLY NAME	From ENV-1 3.3.3B
	AREA: See definition Exterior Roof / Ceiling. Note: Area of opaque exterior surface of the roof / ceiling. Does not include skylights or doors.	3.1.2A 3.3.3B
	PROPOSED HEAT CAPACITY	3.3.3B 3.1.2H
	PROPOSED U-VALUE	3.1.2A Form ENV-3 3.3.3B
	WOOD FRAME	3.1.2D
	METAL FRAME	3.1.2E
	MASONRY	3.1.2F
	TABLE VALUES	3.3.3B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 2 OF 5(cont.)

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT LOSS		
	ROOFS / CEILINGS	
	PROPOSED UA	3.1.2A 3.3.3B
	STANDARD AREA (ADJUSTED) If Skylight Adjustment Factor is required from Column G.	3.1.2A 3.2.3A 3.3.3B
	STANDARD U-VALUE: Nonresidential Buildings	Standards Table 1-H 3.3.3B
	STANDARD U-VALUE: High-rise Residential Bldgs and Guest Rooms of Hotel / Motel Bldgs.	Standards Table 1-I 3.3.3B
	STANDARD UA	3.2.3A 3.3.3B
	FLOORS / SOFFITS	
	PROPOSED ASSEMBLY NAME	From ENV-1 3.3.3B
	AREA: See definition Exterior Roof / Ceiling. Note: Area of opaque exterior surface of the roof / ceiling. Does not include skylights or doors.	3.3.3B
	PROPOSED HEAT CAPACITY	3.3.3B 3.1.2H
	PROPOSED U-VALUE	3.1.2C 3.3.3B FORM ENV-3
	WOOD FRAME	3.1.2D
	METAL FRAME	3.1.2E
	MASONRY	3.1.2F
	TABLE VALUES	3.3.3B
	PROPOSED UA	3.2.3A 3.3.3B
	STANDARD AREA (ADJUSTED)	3.3.3B
	STANDARD U-VALUE: Nonresidential Buildings	Standards Table 1-H 3.3.3B
	STANDARD U-VALUE: High-rise Residential Bldgs and Guest Rooms of Hotel / Motel Bldgs.	Standards Table 1-I 3.3.3B
	STANDARD UA	3.2.3A 3.3.3B
	WINDOWS	
	PROPOSED ASSEMBLY NAME	From ENV-1 3.3.3B
	# OF PANES	3.3.3B
	AREA: See definition Window Area	3.3.3B
	PROPOSED HEAT CAPACITY	3.3.3B 3.1.2H

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 2 OF 5(cont.)

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT LOSS		
	WINDOWS	
	PROPOSED U-VALUE	3.1.2C 3.3.3B
	NON-METAL FRAME	
	METAL FRAME	
	TABLE VALUES	3.3.3B
	PROPOSED UA	3.2.3A 3.3.3B
	STANDARD AREA (ADJUSTED)	3.1.2A 3.3.3B
	STANDARD U-VALUE: Nonresidential Buildings	Standards Table 1-H
	STANDARD U-VALUE: High-rise Residential Bldgs and Guest Rooms of Hotel / Motel Bldgs.	Standards Table 1-I 3.3.3B 3.3.3B
	STANDARD UA	3.3.3B
	SKYLIGHTS	
	PROPOSED ASSEMBLY NAME	From ENV-1 3.3.3B
	# OF PANES	3.3.3B
	AREA: See definition Skylight Area	3.3.3B
	PROPOSED HEAT CAPACITY	3.3.3B 3.1.2H
	PROPOSED U-VALUE	3.1.2C 3.3.3B
	NON-METAL FRAME	
	METAL FRAME	
	TABLE VALUES	3.3.3B
	PROPOSED UA	3.2.3A 3.3.3B
	STANDARD AREA (ADJUSTED)	3.1.2A 3.3.3B
	STANDARD U-VALUE: Nonresidential Buildings	Standards Table 1-H
	STANDARD U-VALUE: High-rise Residential Bldgs and Guest Rooms of Hotel / Motel Bldgs.	Standards Table 1-I 3.3.3B 3.3.3B
	STANDARD UA	3.3.3B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 3 OF 5

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT GAIN FROM CONDUCTION		
	WALLS	
	ASSEMBLY NAME	3.3.3C
	PROPOSED AREA	3.3.3C
	PROPOSED TEMP-FACTOR	3.3.3C Table 3-22 Standards Table 1-J
	PROPOSED HEAT CAPACITY	3.3.3C 3.1.2H
	PROPOSED U-VALUE	3.3.3C Appendix B
	TABLE VALUES?	3.3.3C Table B-7
	PROPOSED HEAT GAIN Q	3.3.3C
	STANDARD AREA (ADJUSTED)	3.3.3C
	STANDARD U-VALUE	3.3.3C Tables 3-20, 3-21
	STANDARD TEMP-FACTOR	3.3.3C
	STANDARD HEAT GAIN Q	3.3.3C
	ROOFS / CEILINGS	
	ASSEMBLY NAME	3.3.3C
	PROPOSED AREA	3.3.3C
	PROPOSED TEMP-FACTOR	3.3.3C Table 3-22 Standards Table 1-J
	PROPOSED HEAT CAPACITY	3.3.3C 3.1.2H
	PROPOSED U-VALUE	3.3.3C Appendix B
	TABLE VALUES?	3.3.3C Table B-7
	PROPOSED HEAT GAIN Q	3.3.3C
	STANDARD AREA (ADJUSTED)	3.3.3C
	STANDARD U-VALUE	3.3.3C Tables 3-20, 3-21
	STANDARD TEMP-FACTOR	3.3.3C
	STANDARD HEAT GAIN Q	3.3.3C
	FLOORS / SOFFITS	
	ASSEMBLY NAME	3.3.3C
	PROPOSED AREA	3.3.3C
	PROPOSED TEMP-FACTOR	3.3.3C Table 3-22 Standards Table 1-J

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 3 OF 5(cont.)

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT GAIN FROM CONDUCTION		
	FLOORS / SOFFITS	
	PROPOSED HEAT CAPACITY	3.3.3C 3.1.2H
	PROPOSED U-VALUE	3.3.3C Appendix B
	TABLE VALUES?	3.3.3C Table B-7
	PROPOSED HEAT GAIN Q	3.3.3C
	STANDARD AREA (ADJUSTED)	3.3.3C
	STANDARD U-VALUE	3.3.3C Tables 3-20, 3-21
	STANDARD TEMP-FACTOR	3.3.3C
	STANDARD HEAT GAIN Q	3.3.3C
	WINDOWS	
	ASSEMBLY NAME	3.3.3C
	PROPOSED AREA	3.3.3C
	PROPOSED TEMP-FACTOR	3.3.3C Table 3-22 Standards Table 1-J
	PROPOSED HEAT CAPACITY	3.3.3C 3.1.2H
	PROPOSED U-VALUE	3.3.3C Appendix B
	TABLE VALUES?	3.3.3C Table B-7
	PROPOSED HEAT GAIN Q	3.3.3C
	STANDARD AREA (ADJUSTED)	3.3.3C
	STANDARD U-VALUE	3.3.3C Tables 3-20, 3-21
	STANDARD TEMP-FACTOR	3.3.3C
	STANDARD HEAT GAIN Q	3.3.3C
	SKYLIGHTS	
	ASSEMBLY NAME	3.3.3C
	PROPOSED AREA	3.3.3C
	PROPOSED TEMP-FACTOR	3.3.3C Table 3-22 Standards Table 1-J
	PROPOSED HEAT CAPACITY	3.3.3C 3.1.2H
	PROPOSED U-VALUE	3.3.3C Appendix B
	TABLE VALUES?	3.3.3C Table B-7
	PROPOSED HEAT GAIN Q	3.3.3C
	STANDARD AREA (ADJUSTED)	3.3.3C

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 3 OF 5(cont.)

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT GAIN FROM CONDUCTION		
	STANDARD U-VALUE	3.3.3C Tables 3-20, 3-21
	STANDARD TEMP-FACTOR	3.3.3C
	STANDARD HEAT GAIN Q	3.3.3C

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 4 OF 5

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	**CONSERVATION MEASURE**	*REFERENCE*
OVERALL HEAT GAIN FROM RADIATION		
	NORTH	
	WINDOW / SKYLIGHT NAME	3.3.3D
	WEIGHTING FACTOR	3.3.3D Table 3-23 Stds Table 1-K
	PROPOSED AREA	3.3.3D 3.1.2A
	PROPOSED SOLAR FACTOR	3.3.3D Table 3-23 Stds Table 1-J
	PROPOSED SHGC	3.3.3D
	OVERHANG	
	H	3.1.2J
	V	3.1.2J
	H/V	3.3.3D
	OHF	3.3.3D
	PROPOSED HEAT GAIN Q	3.3.3D
	STANDARD AREA	3.3.3D
	STANDARD RSHG OR SHGC	3.3.3D Tables 3-20 and 3-21
	STANDARD SOLAR FACTOR	3.3.3D Table 3-22 Stds Table 1-J
	STANDARD HEAT GAIN Q	3.3.3D
	EAST	
	WINDOW / SKYLIGHT NAME	3.3.3D
	WEIGHTING FACTOR	3.3.3D Table 3-23 Stds Table 1-K
	PROPOSED AREA	3.3.3D 3.1.2A
	PROPOSED SOLAR FACTOR	3.3.3D Table 3-23 Stds Table 1-J
	PROPOSED SHGC	3.3.3D
	OVERHANG	
	H	3.1.2J
	V	3.1.2J
	H/V	3.3.3D
	OHF	3.3.3D
	PROPOSED HEAT GAIN Q	3.3.3D
	STANDARD AREA	3.3.3D

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 4 OF 5(cont.)

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT GAIN FROM RADIATION		
	EAST	
	STANDARD RSHG OR SHGC	3.3.3D Tables 3-20 and 3-21
	STANDARD SOLAR FACTOR	3.3.3D Table 3-22 Stds Table 1-J
	STANDARD HEAT GAIN Q	3.3.3D
	SOUTH	
	WINDOW / SKYLIGHT NAME	3.3.3D
	WEIGHTING FACTOR	3.3.3D Table 3-23 Stds Table 1-K
	PROPOSED AREA	3.3.3D 3.1.2A
	PROPOSED SOLAR FACTOR	3.3.3D Table 3-23 Stds Table 1-J
	PROPOSED SHGC	3.3.3D
	OVERHANG	
	H	3.1.2J
	V	3.1.2J
	H/V	3.3.3D
	OHF	3.3.3D
	PROPOSED HEAT GAIN Q	3.3.3D
	STANDARD AREA	3.3.3D
	STANDARD RSHG OR SHGC	3.3.3D Tables 3-20 and 3-21
	STANDARD SOLAR FACTOR	3.3.3D Table 3-22 Stds Table 1-J
	STANDARD HEAT GAIN Q	3.3.3D
	WEST	
	WINDOW / SKYLIGHT NAME	3.3.3D
	WEIGHTING FACTOR	3.3.3D Table 3-23 Stds Table 1-K
	PROPOSED AREA	3.3.3D 3.1.2A
	PROPOSED SOLAR FACTOR	3.3.3D Table 3-23 Stds Table 1-J
	PROPOSED SHGC	3.3.3D
	OVERHANG	
	H	3.1.2J
	V	3.1.2J
	H/V	3.3.3D
	OHF	3.3.3D
	PROPOSED HEAT GAIN Q	3.3.3D

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 4 OF 5(cont.)

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
OVERALL HEAT GAIN FROM RADIATION		
	WEST	
	STANDARD AREA	3.3.3D
	STANDARD RSHG OR SHGC	3.3.3D Tables 3-20 and 3-21
	STANDARD SOLAR FACTOR	3.3.3D Table 3-22 Stds Table 1-J
	STANDARD HEAT GAIN Q	3.3.3D
	SKYLIGHTS	
	WINDOW / SKYLIGHT NAME	3.3.3D
	WEIGHTING FACTOR	3.3.3D Table 3-23 Stds Table 1-K
	PROPOSED AREA	3.3.3D 3.1.2A
	PROPOSED SOLAR FACTOR	3.3.3D Table 3-23 Stds Table 1-J
	PROPOSED SHGC	3.3.3D
	PROPOSED HEAT GAIN Q	3.3.3D
	STANDARD AREA	3.3.3D
	STANDARD RSHG OR SHGC	3.3.3D Tables 3-20 and 3-21
	STANDARD SOLAR FACTOR	3.3.3D Table 3-22 Stds Table 1-J
	STANDARD HEAT GAIN Q	3.3.3D

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-2: OVERALL ENVELOPE METHOD - PART 5 OF 5

Note: This form is for the Overall Envelope Method to determine that the proposed design's overall heat loss, based on the installed insulation and glazing performance, are at least as good as the standard heat gain.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
WINDOW AREA ADJUSTMENT CALCULATIONS		
	WALL NAME	From ENV-1 3.3.3E
	ORIENTATION See definition GROSS EXTERIOR WALL AREA (Sum of Window Area, Door Area, and Exterior Wall Area)	3.1.2A 3.3.3E
	GROSS AREA	3.1.2A 3.3.3E
	DOOR AREA	3.1.2A 3.3.3E
	WINDOW ADJUSTMENT FACTOR	From Part 1 of 5 3.3.3E
	ADJUSTED WINDOW AREA(DXE)	3.2.3A 3.3.3E
	ADJUSTED WALL AREA (B-(F+C))	3.2.3A 3.3.3E
SKYLIGHT AREA ADJUSTMENT CALCULATIONS		
	ROOF NAME	From ENV-1 3.3.3E
	GROSS AREA See definition GROSS EXTERIOR ROOF AREA (Sum of Skylight Area and the Exterior roof / ceiling Area)	3.1.2A 3.3.3E
	SKYLIGHT AREA	3.1.2A 3.3.3E
	SKYLIGHT ADJUSTMENT FACTOR	From Part 1 of 5 3.3.3E
	ADJUSTED SKYLIGHT AREA (CXD)	3.2.3A 3.3.3E
	ADJUSTED ROOF AREA (B-E)	3.2.3A 3.3.3E

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-3: PROPOSED METAL FRAME ASSEMBLY

Note: This form is used to determine the Assembly U-Value for metal framed wall assemblies as an alternative to using the Metal Wall U-Value found in Table B-2, Appendix B; or to determine the Assembly U-Value for a metal framed floor, ceiling, or soffit. Refer to 3.1.2 E for description of the use of Table B-2

CATEGORY	**CONSERVATION MEASURE**	***REFERENCE***
COMPONENT DESCRIPTION		
	ASSEMBLY NAME	From ENV-1 3.3.4A
	ASSEMBLY TYPE Floor. Wall, Ceiling / Roof	3.3.4A
	FRAMING MATERIAL Metal	3.3.4A
	FRAMING SIZE Nominal dimension of framing members	3.3.4A
	FRAMING SPACING 16 or 24 inches on center	3.3.4A
	INSULATION R-VALUE	3.1.2B 3.3.4A
CONSTRUCTION COMPONENTS		
	DESCRIPTION Elements of the assembly including inside/outside surface air films	3.1.2C 3.1.2E 3.3.4B Table B-1 Appendix B
	OUTSIDE/INSIDE SURFACE AIR FILM	Table 3-1 3.3.4B
	SUBTOTAL Rc Combined R-Value of Cavity	3.3.4B
	METAL FRAMING FACTOR MFF	Table 3-5 3.3.4B
	INSULATION R- VALUE	3.1.2B 3.3.4B
	Rc x MFF R-Value	3.1.2E 3.3.4B
	INSULATING SHEATHING R-Value	MFG SPECS DIRECTORY 3.3.4B
	TOTAL R-Value Rt	3.1.2E 3.3.4B
	1/Rt Assembly U-Value Insert at Column D, ENV-2, Part 2	3.1.2E 3.3.4B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-3: PROPOSED MASONRY ASSEMBLY

Note: This form is used to determine the Assembly U-Value for masonry wall assemblies as an alternate to using the Masonry Wall U-Value found in Table B-5 or B-6, Appendix B. Refer to 3.1.2F for description of the use of Table B-5 and B-6. As an alternate, it is permissible to use the method of transverse isothermal planes, ASHRAE Handbook, 1989, Fundamentals, Chapter 22 or the method described in Energy Calculations and Data, Concrete masonry Association of California and Nevada, 1986.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
COMPONENT DESCRIPTION		
	SKETCH OF ASSEMBLY	3.3.5A
	WALL ASSEMBLY NAME	From ENV-1 3.3.5A
	DESCRIPTION OF ASSEMBLY	3.3.5A
WALL R-VALUE, U-VALUE, AND HEAT CAPACITY		
	WALL UNIT THICKNESS Nominal Inches	3.3.5B
	MATERIAL TYPE	3.3.5B
	CORE TREATMENT (Grouted, Perlite, Etc.)	3.3.5B
	WALL R-VALUE Rw	Table B-5, B-6, Appendix B 3.3.5B
	WALL HEAT CAPACITY HC	Table B-5, B-6, Appendix B 3.3.5B
FURRING/INSULATION LAYER (INSIDE and/or OUTSIDE IF ANY)		
	FURRING FRAMING MATERIAL (Wood, Metal, Etc.)	3.1.2F 3.3.5C
	FURRING FRAMING SIZE Nominal Inches	3.1.2F 3.3.5C
	FURRING SPACE INSULATION Type	3.1.2F 3.3.5C
	R-VALUE	3.1.2B 3.3.5C
	EXTERIOR INSULATING LAYER	3.1.2F 3.3.5C
	R-VALUE	3.1.2B 3.3.5C
	FURRING ASSEMBLY EFFECTIVE	3.1.2F 3.3.5C
	R-VALUE	Table B-7 Appendix B 3.3.5C
	EXTERIOR INSULATING LAYER R-VALUE	MFG SPEC 3.3.5C
	INSULATING LAYER R-VALUE	3.3.5C
FURRING/INSULATION LAYER (INSIDE and/or OUTSIDE IF ANY)		
	INSULATION LAYER R-VALUE (Rf)	3.1.2F 3.3.5D
	WALL R-VALUE (Rw)	3.1.2F 3.3.5D
	WALL ASSEMBLY R-VALUE (Rf+Rw)=Rt	3.1.2F 3.3.5D
	WALL ASSEMBLY U-VALUE (1/Rt)	3.1.2F 3.3.5D
	Insert at Column D, ENV-2, Part 2	3.1.2F 3.3.5D

NONRESIDENTIAL PLAN CHECK GUIDE

FORM ENV-3: PROPOSED WOOD FRAME ASSEMBLY

Note: This form is used determine the Assembly U-Value for any construction assembly that is not a metal framed assembly or masonry wall assembly,or is not included in the tables in Appendix B. Refer to Section 3.1.2C for discussion of overall assembly U-Value.

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
COMPONENT DESCRIPTION		
	ASSEMBLY NAME	From ENV-1 3.3.6A
	ASSEMBLY TYPE Floor, Wall, or Ceiling/Roof	3.3.6A
	FRAMING MATERIAL Description of Framing Material	3.3.6A
	FRAMING SIZE Nominal Size of Framing Material	3.3.6A
	FRAMING PERCENTAGE	3.1.2D Table 3-3 3.3.6A
CONSTRUCTION COMPONENTS		
	DESCRIPTION Elements of the assembly including inside/outside surface air films	3.1.2C 3.1.2D 3.3.6B
	CAVITY R-VALUE	Table B-1 3.3.6B
	WOOD FRAME R-VALUE (Rf)	3.3.6B
	HEAT CAPACITY (HC)	3.3.6B
	WALL HEIGHT	3.3.6B
	SPECIFIC HEAT	3.3.6B
	HC (A x B)	3.3.6B
	ASSEMBLY U-VALUE	3.3.6B
	Rf R-Value of Frame Section	3.1.2D 3.3.6B
	TOTAL HC Heat Capacity of Construction Assembly	3.1.2H 3.3.6B
	(1/Rc x [1-(Fr%/100)]) + (1/Rf x Fr%/100) =	3.1.2C 3.3.6B
	ASSEMBLY U-VALUE, where:	3.1.2D 3.3.6B
	Rc = Total R-Value of framing cavity	
	Fr% = Framing Percentage	
	Rf = Total R-Value at wood frame	

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-1: CERTIFICATE OF COMPLIANCE

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
GENERAL		
	DATE: Verify version of Energy Efficiency Standards that apply	2.1.1 Table 1-1 4.3.1A
GENERAL INFORMATION		
	BUILDING CONDITIONED FLOOR AREA	2.1.2
	BUILDING TYPE: Verify Occupancy Group(s) and, if Residential, determine if Nonres or res apply.	2.1.1A 2.1.2B 4.3.1B
	PHASE OF CONSTRUCTION	
	NEW CONSTRUCTION	2.2.6
	ADDITION	2.2.5
	ALTERATION	2.2.4
	METHOD OF COMPLIANCE	4.1.1
	PRESCRIPTIVE	4.1.1 4.2.2
	PERFORMANCE	4.1.1 4.2.3
	PROOF OF ENVELOPE COMPLIANCE	
	PREVIOUS ENVELOPE PERMIT	
	ENVELOPE COMPLIANCE ATTACHED	
STATEMENT OF COMPLIANCE		
	CIVIL ENGINEER, MECHANICAL ENGINEER, ELECTRICAL ENGINEER, OR ARCHITECT	4.3.1C
	CONTRACTOR DESIGNING WORK CONTRACTED TO PERFORM	4.3.1C
	OTHERWISE EXEMPT: APPLICANT TO STATE REASON FOR EXEMPTION.	4.3.1C
MECHANICAL MANDATORY MEASURES		
	MANDATORY MEASURES	4.1.1 4.2.1 4.3.1D

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-1: CERTIFICATE OF COMPLIANCE(cont.)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
SYSTEM FEATURES		
	TIME CONTROLS	4.2.1G 4.2.1H 4.3.1E
	SETBACK CONTROLS	4.2.1G 4.2.1H 4.3.1E
	ISOLATION ZONES	4.2.1G 4.2.1H 4.3.1E
	HEAT PUMP THERMOSTAT	4.2.4A.9 4.2.4B.10 4.3.1E
	ELECTRIC HEAT	4.2.2H 4.2.4A.6 4.3.1E
	FAN CONTROL	4.2.2C PLANS 4.3.1E
	VAV MINIMUM POSITION CONTROL	4.2.4B 4.2.4C 4.2.4D 4.2.4E 4.3.1E PLANS
	SIMULTANEOUS HEAT / COOL	4.2.2D.3 4.3.1E
	HEAT SUPPLY RESET	4.2.4D.10 4.3.1E
	COOL SUPPLY RESET	4.2.4D.10 4.3.1E
	VENTILATION	4.2.1F 4.3.1E
	OUTDOOR DAMPER CONTROL	4.2.1F 4.3.2D.12 4.3.1E
	ECONOMIZER TYPE	4.1.2G 4.3.1E
	DESIGN AIR CFM	4.2.1F 4.3.1E
	HEATING EQUIPMENT	4.3.1E
	TYPE	4.2.1 4.3.1E
	HIGH EFFICIENCY	4.3.1E
	MAKE AND MODEL NUMBER	4.3.1E
	COOLING EQUIPMENT TYPE	4.3.1E
	PIPE INSULATION REQUIRED?	4.3.1E
	PIPE TYPE	4.2.1I
	HEATING DUCT LOCATION	4.3.1E
	COOLING DUCT LOCATION	4.3.1E
	DUCT TAPE ALLOWED?	4.2.1J

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-2: MECHANICAL EQUIPMENT SUMMARY (PART 1 OF 2)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
CHILLER AND TOWER SUMMARY		
	EQUIPMENT NAME	4.3.2A
	EQUIPMENT TYPE	4.3.2A
	QTY	4.3.2A
	EFFICIENCY	Table B-9
	TONS	4.3.2A
	PUMPS TOTAL QTY	4.3.2A
	PUMPS GPM	4.3.2A
	PUMPS BHP	4.3.2A
	PUMPS MOTOR EFF.	Table B-8
	PUMPS DRIVE EFF.	4.3.2A
	PUMPS PUMP CONTROL	4.3.2A
DHW / BOILER SUMMARY		
	SYSTEM NAME	4.3.2B
	SYSTEM TYPE	4.3.2B
	DISTRIBUTION TYPE	4.3.2B
	QTY.	4.3.2B
	RATED INPUT	4.3.2B
	VOL.(GALS.)	4.3.2B
	ENERGY FACTOR OR RECOVERY EFFICIENCY	4.3.2B
	STANDBY LOSS OR PILOT	4.3.2B
	TANK INSUL.	4.3.2B
CENTRAL SYSTEM RATINGS		
	SYSTEM NAME	4.3.2C
	SYSTEM TYPE	4.3.2C
	QTY.	4.3.2C
	HEATING OUTPUT	4.3.2C
	HEATING AUX KW	4.3.2C
	HEATING EFFICIENCY	Table B-9
	COOLING OUTPUT	4.3.2C
	COOLING SENSIBLE	4.3.2C
	COOLING EFFICIENCY	Table B-9
	COOLING ECONOMIZER TYPE	4.3.2C

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-2: MECHANICAL EQUIPMENT SUMMARY (PART 1 OF 2) (cont.)

CATEGORY	**CONSERVATION MEASURE**	***REFERENCE***
CENTRAL FAN SUMMARY		
	SYSTEM NAME	4.3.2D
	FAN TYPE	4.3.2D
	MOTOR LOCATION	4.3.2D
	SUPPLY FAN CFM	4.3.2D
	SUPPLY FAN BHP	4.2.2C
	SUPPLY FAN MOTOR EFF.	Table B-8
	SUPPLY FAN DRIVE EFF.	4.3.2D
	RETURN FAN CFM	4.3.2D
	RETURN FAN BHP	4.2.2C
	RETURN FAN MOTOR EFF.	Table B-8
	RETURN FAN DRIVE EFF.	4.3.2D

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-2: MECHANICAL EQUIPMENT SUMMARY (PART 2 OF 2)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
VAV SUMMARY		
	ZONE NAME	4.3.2E
	VAV SYSTEM TYPE	4.3.2E
	VAV QTY.	4.3.2E
	VAV MIN. CFM RATIO	4.3.2E
	VAV TYPE	4.3.2E
	VAV DELTA T	4.3.2E
	FAN FLOW RATIO	4.3.2E
	FAN CFM	4.3.2E
	FAN BHP	4.2.2C
	FAN MOTOR EFF.	Table B-8
	FAN DRIVE EFF.	4.3.2E
	BASEBOARD TYPE	4.3.2E
	BASEBOARD OUTPUT	4.3.2E
EXHAUST FAN SUMMARY		
	EXHAUST FAN SUMMARY	4.3.2F
	ROOM NAME	4.3.2F
	QTY.	4.3.2F
	CFM	4.3.2F
	BHP	4.2.2C
	MOTOR EFF.	Table B-8
	DRIVE EFF	4.3.2F

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-3: MECHANICAL VENTILATION

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
VENTILATION CALCULATIONS		
	ZONE / SYSTEM	PLANS / SPECS
	AREA BASIS	
	COND. AREA	PLANS / SPECS
	CFM / SF	ASHRAE STD 62-1989
	MIN CFM	CALCULATED
	OCCUPANCY BASIS	
	NO. OF PEOPLE	PLANS / SPECS
	CFM / PERSON	4.2.1F
	MIN CFM	CALCULATED
	REQ'D O.A.	4.3.3A
	DESIGN OUTDOOR AIR CFM	4.3.3A
	VAV MINIMUM CFM	4.3.3A
	LARGEST MIN CFM	4.3.4
	DESIGN MIN CFM	4.3.4
	TRANSFER AIR	CALCULATED 4.3.4

NONRESIDENTIAL PLAN CHECK GUIDE

FORM MECH-4: MECHANICAL SIZING AND FAN POWER

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
SIZING AND EQUIPMENT SELECTION		
	DESIGN CONDITIONS	ASHRAE
	OUTDOOR , DRY BULB TEMPERATURE	4.2.2B
	OUTDOOR , WET BULB TEMPERATURE	4.3.4A
	INDOOR, DRY BULB TEMPERATURE	APPENDIX C
	SIZING	4.2.2A 4.3.4A
	DESIGN OUTDOOR AIR	4.3.4A APPENDIX C
	ENVELOPE LOAD	4.2.2B.6 4.3.4.A
	LIGHTING	4.2.2.B.7 4.3.4A
	PEOPLE	Form MECH-4
	MISC. EQUIPMENT	ASHRAE STDS 4.3.4A
	OTHER	ASHRAE STDS 4.3.4A
	OTHER LOADS/SAFETY FACTOR	4.3.4A
	MAXIMUM ADJUSTED LOAD	4.3.4A
	INSTALLED EQUIPMENT CAPACITY	MANUF. DATA 4.3.4A
FAN POWER CONSUMPTION		
	FAN DESCRIPTION	4.2.2C 4.3.4B
	DESIGN BRAKE HORSEPOWER	MANUF. DATA
	EFFICIENCY	PLANS/SPECS 4.3.4B
	NUMBER OF FANS	PLANS/SPECS 4.3.4B
	PEAK WATTS	4.3.4B
	CFM	PLANS/SPECS 4.3.4B
	TOTALS	4.3.4B
	TOTAL FAN SYSTEM POWER DEMAND	4.3.4B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-1: CERTIFICATE OF COMPLIANCE (PART 1 OF 2)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
GENERAL		
	DATE	2.1.1 Table 1-I 5.3.1A
GENERAL INFORMATION		
	BUILDING CONDITIONED FLOOR AREA	2.1.2A 5.3.1A
	CLIMATE ZONE	APPENDIX C 5.3.1A
	BUILDING TYPE: Verify Occupancy Group(s) and if Residential determine whether NonRes or Res Standards apply.	2.1.1 2.1.2B 5.3.1A
	PHASE OF CONSTRUCTION	
	NEW CONSTRUCTION	2.2.2 5.3.1A
	ADDITION	2.2.5 5.3.1A
	ALTERATION	2.2.4 5.3.1A
	UNCONDITIONED	2.2.1 5.3.1A
	METHOD OF COMPLIANCE	5.1.1 5.3.1A
	AREA CATEGORY	5.2.2B 5.3.1A
	TAILORED	5.2.2C 5.3.1A
	PERFORMANCE	5.2.3 5.3.1A
STATEMENT OF COMPLIANCE		
	CIVIL ENGINEER, MECHANICAL ENGINEER, ELECTRICAL ENGINEER, OR ARCHITECT. CONTRACTOR DESIGNING WORK CONTRACTED TO PERFORM OTHERWISE EXEMPT: APPLICANT TO STATE REASON FOR EXEMPTION	5.3.1A B&P CODE

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-1: CERTIFICATE OF COMPLIANCE (PART 1 OF 2) (cont.)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
LIGHTING MANDATORY MEASURES		
	CONTROL REQUIREMENTS	5.2.1A 5.3.1A
	AREA REQUIREMENTS	5.2.1A 5.3.1A
	ROOM SWITCHING	5.2.1A 5.3.1A
	ACCESSIBILITY	5.2.1A 5.3.1A
	PUBLIC AREAS	5.2.1A 5.3.1A
	SECURITY OR EMERGENCY	5.2.1A 5.3.1A
	OTHER DEVICES	5.2.1A 5.3.1A
	BI-LEVEL SWITCHING	5.2.1B 5.3.1A
	DAYLIT AREAS	5.2.1C 5.3.1A
	EFFECTIVE APERTURE	5.2.1C 5.3.1A
	VISIBLE LIGHT TRANSMITTANCE (VLT)	5.2.1C 5.3.1A
	WELL INDEX	5.2.1C 5.3.1A
	DISPLAY LIGHTING	5.2.1E 5.3.1A
	SHUT-OFF CONTROLS	5.2.1D 5.3.1A
	EXTERIOR LIGHTS	5.2.1F 5.3.1A
	TANDEM WIRING	5.2.1G 5.3.1A
	HIGH RISE RESIDENTIAL AND HOTEL / MOTEL GUEST ROOMS	5.2.1J 5.3.1A
	KITCHEN LIGHTING	5.2.1J 5.3.1A
	BATHROOM LIGHTING	5.2.1J 5.3.1A
	GENERAL	5.2.1J 5.3.1A
	CERTIFIED AUTOMATIC LIGHTING CONTROL DEVICES	5.2.1H 5.3.1A
	AUTOMATIC TIME SWITCHES (ATS)	5.2.1H 5.3.1A
	OCCUPANCY SENSORS	5.2.1H 5.3.1A
	AUTOMATIC DAYLIGHT CONTROLS	5.2.1H 5.3.1A
	LUMEN MAINTENANCE CONTROL	5.2.1H 5.3.1A
	INTERIOR PHOTOCELL	5.2.1H 5.3.1A
	CERTIFIED BALLASTS AND LUMINAIRES	5.2.1I 5.3.1A

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-1: CERTIFICATE OF COMPLIANCE (PART 2 OF 2)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
INSTALLED LIGHTING SCHEDULE		
	DESCRIPTION: To identify for attached forms	Same as LTG-1 5.3.1B
	LAMPS	5.3.1B
	TYPE description	5.3.1B
	#	5.3.1B
	WATTS PER LAMP	5.3.1B 5.2.4
	BALLAST	5.3.1B
	TYPE description	5.3.1B
	#	5.3.1B
	LUMINAIRE	5.3.1B
	#	5.3.1B
	WATTS	5.3.1B
	TOTAL WATTS	5.3.1B
	I=INCANDESCENT	5.3.1B
	F=FLOURESCENT	5.3.1B
	H=HIGH INTENSITY DISCHARGE	5.3.1B
	BALLASTS	5.3.1B
	S=STANDARD MAGNETIC	Directory of Certified Ballasts
	E=ELECTRONIC HIGH FREQUENCY	Supporting documents required
	O=OTHER	Supporting documents required
MANDATORY AUTOMATIC CONTROLS		
	CONTROL LOCATION: To identify for attachment forms	5.2.1A 5.3.1B
	CONTROL IDENTIFICATION	5.2.1A 5.3.1B
	CONTROL TYPE	5.2.1A 5.3.1B
	BUILDING SHUT OFF	5.2.1A 5.3.1B
	INDIVIDUAL ROOM CONTROL	5.2.1A 5.3.1B
	CONTROL OF EXTERIOR LIGHTS	5.2.1A 5.3.1B
	SPACE CONTROLLED	5.2.1A 5.3.1B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-2: LIGHTING COMPLIANCE

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
ACTUAL LIGHTING POWER		
	LUMINAIRE NAMES	From LTG-1
	DESCRIPTION	5.3.2A
	NUMBER OF LUMINAIRES	5.3.2A
	WATTS PER LUMINAIRE	5.3.2A
	CEC DEFAULT:	CEC Directory
	Y=Data is a standard value from data references. N= Manufacturer's data sheets are LESS CONTROL CREDITS: Form LTG-3 is required.	
	TOTAL WATTS	5.3.2A
	ADJUSTED ACTUAL WATTS Must be equal to or less than the allowed Watts.	5.2.4A 5.2.4B 5.3.2A
ALLOWED LIGHTING POWER (Choose one Method)		
	COMPLETE BUILDING METHOD	5.2.2A 5.3.2B
	BUILDING CATEGORY	Table 5-3 5.3.2B
	WATTS PER SF	Table 5-3 5.3.2B
	COMPLETE BUILDING AREA	Form LTG-1 5.3.2B
	ALLOWED WATTS	watts/sf x BLDG AREA 5.3.2B
	AREA CATEGORY METHOD	5.2.2B 5.3.2B
	AREA CATEGORY	Table 5-4 5.3.2B
	WATTS PER SF	5.3.2B
	ALLOWED LIGHTING POWER	Table 5-4 5.3.2B
	AREA (SF)	5.2.2B PLANS 5.3.2B
	ALLOWED WATTS	watts/sf x AREA SF 5.3.2B
	TOTAL AREA	Form LTG-1 5.3.2B
	TOTAL WATTS	ALLOWED WATTS 5.3.2B
	TAILORED METHOD	5.2.2C 5.3.2B
	TAILORED METHOD TOTAL ALLOWED WATTS	5.3.2B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-3: LIGHTING CONTROLS CREDIT WORKSHEET

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
WORKSHEET		
	Used for credit for lighting controls not required as mandatory measures.	
	ROOM # ZONE ID	Form LTG-1 5.3.3
	LIGHTING CONTROL DESCRIPTION	Form LTG-1 5.3.3
	OCCUPANCY SENSOR	5.1.2D 5.3.3
	DIMMING SYSTEM	5.1.2D 5.3.3
	LUMEN MAINTENANCE CONTROLS	5.1.2D 5.3.3
	TUNING	5.1.2D 5.3.3
	AUTOMATIC TIME SWITCH CONTROL DEVICE	5.1.2D 5.3.3
	COMBINED CONTROLS	5.1.2D 5.3.3
	PLANS REF. Location for details on plans.	5.3.3
	ROOM AREA SF Square footage of room or area included in control devices.	5.3.3 5.3.3
	DAYLIGHTING To be completed for daylight controls	5.3.3
	ROOM RATIO	5.3.3
	WINDOW WALL RATIO	5.2.1C 5.3.3
	SKYLIGHT / CEILING	5.2.1C 5.3.3
	GLAZING VLT	5.2.1C 5.3.3
	WATTS OF CONTROL LIGHTING Connected Watts of fixtures under control	5.3.3
	LIGHTING ADJUSTMENT FACTOR	Table 5-10 5.3.3
	CONTROL CREDIT WATTS	(Col G x Col H) 5.3.3
	BUILDING TOTAL To be entered on the LTG-2 "Less Control Credits"	5.3.3

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-4: TAILORED LPD SUMMARY AND WORKSHEET(part 1 of 3)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
TAILORED LPD SUMMARY		
	WATTS FOR ILLUMINANCE CATEGORIES A-D	5.2.2C 5.3.4A
	WATTS FOR ILLUMINANCE CATEGORIES E-I	Appendix B 5.3.4A
	WATTS FOR DISPLAY LIGHTING	5.2.2C 5.3.4A
	TOTAL ALLOWED WATTS	5.2.2C 5.3.4A
TAILORED LPD - ILLUMINANCE CATEGORIES A,B,C, AND D		
	ROOM NUMBER	PLANS 5.3.4A
	TASK / ACTIVITY	5.2.2C 5.3.4A
	IES ILLUM. CATEGORY	IES Handbook (Appendix B) 5.3.4A
	ROOM CAVITY RATIO	5.2.2C 5.3.4A
	FLOOR AREA	PLANS
	ALLOWED LPD	Table 5-7 5.3.4A
	ALLOWED WATTS	To Tailored LPD Summary Line 1

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-4: TAILORED LPD SUMMARY AND WORKSHEET (part 2 of 3)

CATEGORY	**CONSERVATION MEASURE**	***REFERENCE***
TAILORED LPD - ILLUMINANCE CATEGORIES E,F,G,H,I, AND GROSS SALES		
Note: Areas adjacent to tasks	TASK / ACTIVITY	5.2.2C 5.3.4B
of Categories F,G,H, and I must be	ILLUMINANCE CATEGORY	IES Handbook (Appendix B) 5.3.4B
assigned a category between	RCR (If E) Room Cavity Ratio	5.2.2C 5.3.4B
A and D.	NOTES: Note Mounting Height or Throw Distance (Gross Sales)	5.2.2C 5.3.4B
	ALLOWED WATTS	5.2.2C 5.3.4B
	TASK AREA (sf)	PLANS 5.3.4B
	ALLOWED LPD	Table 5-7, 5-8 5.3.4B
	ALLOTTED WATTS	Task Areas Allotted LPD 5.3.4B
	DESIGN WATTS	5.3.4B
	LUMIN CODE	Form LTG-1 5.3.4B
	QTY (Number of Luminaries)	Form LTG-1 5.3.4B
	WATTS / LUMIN.	CEC Directory Table B-11 5.3.4B
	DESIGN WATTS	Qty. x watts / lumen
	ALLOWED WATTS The Smaller of Allotted Watts or Design Watts	To Tailored LPD Summary Line 2
TAILORED LPD - PUBLIC AREA DISPLAYS		
Note: Refer to definition	TASK / ACTIVITY	5.2.2C 5.3.4B
"DISPLAY", "PUBLIC AREA",	THROW DIST.	5.2.2C 5.3.4B
5.2.2C.	MOUNTING HEIGHT	5.2.2C 5.3.4B
	ALLOTTED WATTS	
	TASK AREA (sf)	PLANS
	ALLOWED LPD	Table 5-7 5.3.4B
	ALLOTTED WATTS	Task Area x Allowed LPD 5.3.4B
	DESIGN WATTS	
	LUMEN CODE	Form LTG-1 5.3.4B
	QTY (Number of luminaires)	Form LTG-1 5.3.4B
	WATTS / LUMIN	Form LTG-1 5.3.4B Table B-11
	DESIGN WATTS	Qty. x watts / lamp
	ALLOWED WATTS (The Smaller of Allotted Watts or Design)	To Tailored LPD Summary Line 3
	MAXIMUM AREA PUBLIC DISPLAYS=10% of Public Display Area	5.2.2C 5.3.4B

NONRESIDENTIAL PLAN CHECK GUIDE

FORM LTG-4: TAILORED LPD SUMMARY AND WORKSHEET (part 3 of 3)

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
TAILORED LPD - SALES FEATURE FLOOR DISPLAYS		
Note: Refer to definition	TASK / ACTIVITY	PLANS 5.3.4C
"DISPLAY", "SALES FEATURE	THROW DIST.	5.2.2C 5.3.4C
FLOOR", 5.2.2C	MOUNTING HEIGHT	5.2.2C 5.3.4C
	ALLOTTED WATTS	
	TASK AREA (SF)	PLANS
	CAT. G LPD	Table 5-8 5.3.4C
	ALLOTTED WATTS (D x E)	Task Area x CAT.G LPD 5.3.4C
	DESIGN WATTS	
	LUMEN CODE	Form LTG-1 5.3.4C
	QTY.	Form LTG-1 5.3.4C
	WATTS / LUMEN	Form LTG-1 5.3.4C Table B-11
	DESIGN WATTS (H x I)	Qty. x watts / lamp
	ALLOWED WATTS (The smaller of Allotted watts or Design watts)	To Tailored LPD Summary Line 3
	TOTAL AREA FLOOR DISPLAYS	PLANS
	GROSS SALES FLOOR AREA. Maximum area floor displays= 10% of the gross sales floor area.	5.2.2C 5.3.4C
TAILORED LPD - SALES FEATURE WALL DISPLAYS		
	TASK / ACTIVITY	PLANS 5.3.4C
	THROW DIST.	5.2.2C 5.3.4C
	ALLOTTED WATTS	5.2.2C 5.3.4C
	TASK AREA (SF)	PLANS
	ALLOTTED WATTS (C x D)	Task Area x Allowed LPD 5.3.4C
	ALLOWED LPD	Table 5-7 5.3.4C
	LUMEN CODE	Form LTG-1 5.3.4C
	QUANTITY (No. of Lamps)	Form LTG-1 5.3.4C
	WATTS / LUMEN.	Form LTG-1 5.3.4C Table B-11
	DESIGN WATTS (G x H)	Qty. x Watts / lamp
	ALLOWED WATTS (The Smaller of Allotted watts or Design watts)	5.3.4C
	TOTAL AREA WALL DISPLAYS	PLANS
	GROSS SALES WALL AREA. Maximum area wall displays= 10% of gross sales floor area.	

FORM LTG-5: ROOM CAVITY RATIO WORKSHEET

CATEGORY	CONSERVATION MEASURE	*REFERENCE*
RECTANGULAR SPACES		
	ROOM NUMBER	5.3.5B
	TASK / ACTIVITY DESCRIPTION	5.3.5B
	ROOM LENGTH (L)	5.3.5B
	ROOM WIDTH (W)	5.3.5B
	ROOM HEIGHT (H)	5.3.5B
	ROOM CAVITY RATIO = [5 x H x(L+W) / (L x W)]	5.3.5B
NON-RECTANGULAR SPACES		
	ROOM NUMBER	5.3.5C
	TASK / ACTIVITY DESCRIPTION	5.3.5C
	ROOM AREA (A)	5.3.5C
	ROOM PERIMETER (P)	5.3.5C
	ROOM CAVITY HEIGHT (H)	5.3.5C
	ROOM CAVITY RATIO = [(2.5 x H x P) / A]	5.3.5C

NONRESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

INSPECTION CHECKLIST

FIELD INSPECTION GUIDELINE

NOTE: The 1998 Energy Efficiency Standards for Nonresidential Buildings apply to buildings of Occupancy Groups A, B, E, F, H, M, and S; to High Rise Residential occupancy; and to Hotel/Motel Guest Rooms. The Energy efficiency Standards govern Envelope, Mechanical Systems, and Lighting Systems.

FOUNDATION INSPECTION

CATEGORY	*FEATURE*	*CONSERVATION MEASURE*	*REFERENCE*
ORIENTATION			PLANS
STRUCTURAL:			
	BUILDING DIMENSIONS	CONDITIONED FLOOR AREA	ENV-1 GENERAL INFO
	SLAB EDGE/BASEMENT OR FOUNDATION	CERTIFIED INSULATION MATERIALS	MANDATORY MEASURE
	FOUNDATION WALL	U-VALUE OF INSULATION	ENV-1 OPAQUE
	MASS WALLS	HEAT CAPACITY	ENV-2 OPAQUE
MECHANICAL:			
	BUILDING DIMENSIONS	CONDITIONED FLOOR AREA	MECH-1 GENERAL INFO
LIGHTING:			
	BUILDING DIMENSIONS	CONDITIONED FLOOR AREA	LTG-1 GENERAL INFO

NONRESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

INSPECTION CHECKLIST

FIELD INSPECTION GUIDELINE

NOTE: The 1998 Energy Efficiency Standards for Nonresidential Buildings apply to buildings of Occupancy Groups A, B, E, F, H, M, and S; to High Rise Residential occupancy; and to Hotel/Motel Guest Rooms. The Energy efficiency Standards govern Envelope, Mechanical Systems, and Lighting Systems.

CONCRETE SLAB OR UNDER-FLOOR INSPECTION

CATEGORY	*FEATURE*	*CONSERVATION MEASURE*	*REFERENCE*
STRUCTURAL:			
	SLAB-EDGE/UNDER FLOOR	CERTIFIED INSULATION	MANDATORY MEASURES
	INSULATION	U-VALUE OF INSULATION MATERIALS	ENV-1 OPAQUE
	FLOOR MASS	MATERIALS HEAT CAPACITY	ENV-2 OPAQUE
MECHANICAL:			
	DUCT/PIPING	LOCATION	MECH-1 PART 2
		TYPE	MECH-1 PART 2
		INSULATION R-VALUE	MECH-1 PART 2
		DUCT TAPE ALLOWED?	MECH-1 PART 2
LIGHTING:			
	CONDUIT/RACEWAY	CONTROL REQUIREMENTS	MANDATORY MEASURE
		Area requirements	
		Room switching	
		Accessibility	
		Other devices	
		Bi-level reduction illumination	
		Exterior lights	
		Display lighting	
		Shut-off controls	
		Display lighting	
		MANDATORY AUTOMATIC CONTROLS	LTG-1 PART 2
		CONTROLS FOR CREDIT	LTG-3

NONRESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

INSPECTION CHECKLIST

FIELD INSPECTION GUIDELINE

NOTE: The 1998 Energy Efficiency Standards for Nonresidential Buildings apply to buildings of Occupancy Groups A, B, E, F, H, M, and S; to High Rise Residential occupancy; and to Hotel/Motel Guest Rooms. The Energy efficiency Standards govern Envelope, Mechanical Systems, and Lighting Systems.

FRAME INSPECTION

CATEGORY	*FEATURE*	*CONSERVATION MEASURE*	*REFERENCE*
STRUCTURAL:			
	FENESTRATION	CERTIFICATION	MANDATORY MEASURE
		ROUGH-IN DIMENSIONS	PLANS
		ORIENTATION	PLANS
		EXTERIOR OVERHANG	ENV-1 EXTERIOR SHADING
	EXTERIOR DOORS	CAULKING	MANDATORY MEASURE
		WEATHER-STRIP	MANDATORY MEASURE
	WINDOWS	MANUFACTURED	
		Label	MANDATORY MEASURE
		U-value	ENV-1 FENESTRATION
		Solar Heat Gain Coefficient	ENV-1 FENESTRATION
		Caulking	MANDATORY MEASURE
		SITE CONSTRUCTED	
		Solar Heat Gain Coefficient	ENV-1 FENESTRATION
		Caulking	MANDATORY MEASURE
		Weather-stripping	MANDATORY MEASURE
	SKYLIGHTS	MANUFACTURED	
		Label	MANDATORY MEASURE
		U-value	ENV-1 FENESTRATION
		Solar Heat Gain Coefficient	ENV-1 FENESTRATION
		Caulking	MANDATORY MEASURE
		SITE CONSTRUCTED	
		Solar Heat Gain Coefficient	ENV-1 FENESTRATION
		Caulking	MANDATORY MEASURE
		Weather-stripping	MANDATORY MEASURE
	EXTERIOR WALLS/DEMISING	CONSTRUCTION TYPE	ENV-1 OPAQUE
	PARTITIONS	MASS/HEAT CAPACITY	ENV-2 OPAQUE
	ROOF/CEILING	CONSTRUCTION TYPE	ENV-1 OPAQUE
	ROOF/CEILING	CONSTRUCTION TYPE	ENV-1 OPAQUE

FRAME INSPECTION (CONTINUED)

CATEGORY	*FEATURE*	*CONSERVATION MEASURE*	*REFERENCE*
STRUCTURAL (CONTINUED):			
	FLOOR/SOFFIT	CONSTRUCTION TYPE	ENV-1 OPAQUE
MECHANICAL:			
	DUCT/PIPING	LOCATION	MECH-1 PART 2
		TYPE	MECH-1 PART 2
		INSULATION R-VALUE	MECH-1 PART 2
		DUCT TAPE ALLOWED	MECH-1 PART 2
	CONTROLS (WIRING FOR)	NUMBER OF SYSTEMS/ZONES	MECH-1 PART 2
		THERMOSTAT/TIME CONTROLS	MECH-1 PART 2
		PER ZONE	
LIGHTING:			
	CONDUIT/RACEWAY	CONTROL REQUIREMENTS	MANDATORY MEASURE
		Area requirements	
		Room switching	
		Accessibility	
		Other devices	
		Bi-level reduction illumination	
		Daylight areas	
		Display lighting	
		Shut-off controls	
		Exterior lights	
		MANDATORY AUTOMATIC CONTROLS	LTG-1 PART 2
		Building shut-off	
		Individual room control	
		Control of exterior lights	
		TANDEM WIRING	
		One or three lamp luminaries	MANDATORY MEASURE
		CONTROLS FOR CREDIT	LTG-3
		Occupancy sensor	
		Dimming switch	
		Lumen maintenance controls	
		Tuning	
		Automatic time switch control	
		Combined controls	

NONRESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

INSPECTION CHECKLIST

FIELD INSPECTION GUIDELINE

NOTE: The 1998 Energy Efficiency Standards for Nonresidential Buildings apply to buildings of Occupancy Groups A, B, E, F, H, M, and S; to High Rise Residential occupancy; and to Hotel/Motel Guest Rooms. The Energy efficiency Standards govern Envelope, Mechanical Systems, and Lighting Systems.

INSULATION INSPECTION

CATEGORY	*FEATURE*	*CONSERVATION MEASURE*	*REFERENCE*
STRUCTURAL:			
	EXTERIOR WALLS/	CONSTRUCTION TYPE	ENV-1 OPAQUE
	DEMISING PARTITIONS	MASS/HEAT CAPACITY	ENV-2 OPAQUE
		INSULATION R-VALUE	ENV-2 OPAQUE
		CERTIFIED INSULATION MATERIALS	MANDATORY MEASURES
	ROOF/CEILING	CONSTRUCTION TYPE	ENV-1 OPAQUE
		INSULATION R-VALUE	ENV-2 OPAQUE
		CERTIFIED INSULATION MATERIALS	MANDATORY MEASURES
	FLOOR/SOFFIT	CONSTRUCTION TYPE	ENV-1 OPAQUE
		INSULATION R-VALUE	ENV-2 OPAQUE
		CERTIFIED INSULATION MATERIALS	MANDATORY MEASURES

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FINAL INSPECTION

CATEGORY	***FEATURE***	***CONSERVATION MEASURE***	***REFERENCE***
MECHANICAL:			
	SYSTEM TYPE	HEATING - MAKE/MODEL	MECH-1 SYSTEM FEATURES
		COOLING - MAKE/MODEL	MECH-1 SYSTEM FEATURES
		VENTILATION - NATURAL/MECHANICAL	MECH-1 SYSTEM FEATURES
		ECONOMIZER	MECH-1 SYSTEM FEATURES
	CONTROLS	NUMBER OF SYSTEMS/ZONES	MECH-1 PART 2
		THERMOSTAT/TIME HEATPUMP	MECH-1 PART 2
		CONTROLS PER ISOLATION ZONE	MECH-1 PART 2
LIGHTING:			
	CONTROL	AREA REQUIREMENTS	MANDATORY MEASURE
		Room switching	
		Control or occupancy sensor in each area	
		Accessibility	
		Control within sight of the controlled area	
		Other devices	
		Special devices or overrides	
		BI-LEVEL REDUCTION ILLUMINATION	MANDATORY MEASURE
		> 100sf and > 1.2 Watts/sf	
		DAYLIT AREAS	MANDATORY MEASURE
		>250sf and windows or skylights	
		Separate switching	
		DISPLAY LIGHTING	MANDATORY MEASURE
		Feature display in retail store	
		Separate switching	
		SHUT-OFF CONTROLS	MANDATORY MEASURE
		>5,000sf with automatic time switch	
		EXTERIOR LIGHTS	MANDATORY MEASURE
		Photocell or automatic time switch	

FINAL INSPECTION (CONTINUED)

CATEGORY	FEATURE	CONSERVATION MEASURE	REFERENCE
LIGHTING (CONTINUED)			
	TANDEM WIREING	ONE OR THREE LUMINAIRES	MANDATORY MEASURE
	MANDATORY AUTOMATIC BUILDING SHUT-OFF CONTROLS		LTG-1
	CONTROLS FOR CREDIT	OCCUPANCY SENSOR	LTG-3
		Time delay	
		DIMMING SYSTEM	LTG-3
		Uniform reduction to 1/2	
		Flicker free operation	
		Time delay	
		LUMIN MAINTENANCE CONTROLS	LTG-3
		Alarm	
		TUNING	LTG-3
		AUTOMATIC TIME SWITCH CONTROL DEVICE	LTG-3
		Separate programs for weekend/holidays	
		Override switching	
		Ten hour backup power	
		COMBINED CONTROLS	LTG-3
	LUMINAIRES	TYPE	LTG-1
		Incandescent	
		Florescent	
		High-intensity discharge	
		NUMBER OF LAMPS	LTG-1
		WATTS PER LAMP	LTG-1
		BALLASTS	LTG-1
		Standard magnetic	
		Electronic high frequency	
		Other	
		Number per luminaire	