



Arnold Schwarzenegger  
*Governor*

# WHOLE HOUSE CONTRACTING PROTOCOLS PROJECT

## VOLUME 2

### REFERENCE MANUAL FOR INSTRUCTORS: BEST PRACTICE PROTOCOLS FOR HOME PERFORMANCE CONTRACTORS

*Prepared For:*

**California Energy Commission**  
Public Interest Energy Research Program

*Prepared By:*

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## Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

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For more information about the PIER Program, please visit the Energy Commission's website at [www.energy.ca.gov/pier](http://www.energy.ca.gov/pier) or contact the Energy Commission at 916-654-5164.

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## Table of Contents

Preface .....	i
Abstract .....	vii
Executive Summary .....	1
1.0 Introduction–Benefits to California .....	5
2.0 Inspection and Diagnosis—General .....	21
3.0 Inspection and Diagnosis—Customer Concern Interviewing .....	25
4.0 Inspection and Diagnosis—Site Inspection .....	31
5.0 Inspection and Diagnosis—Health, Durability, Indoor Air Quality, and Safety .....	37
6.0 Inspection and Diagnosis—Moisture .....	45
7.0 Inspection and Diagnosis—Mechanical Ventilation Systems .....	51
8.0 Inspection and Diagnosis—Carbon Monoxide .....	57
9.0 Inspection and Diagnosis—Combustion Appliance Zones.....	67
10.0 Inspection and Diagnosis—Heat Exchangers .....	71
11.0 Inspection and Diagnosis—Combustion Efficiency, Flue Capacity, HVAC, and DHW .....	77
12.0 Inspection and Diagnosis—Appliance Venting and Vent Pressure.....	91
13.0 Inspection and Diagnosis—Building Envelope .....	97
14.0 Inspection and Diagnosis—Thermal Boundary .....	103
15.0 Inspection and Diagnosis—Blower Door Test .....	107
16.0 Inspection and Diagnosis—Transition Zones .....	113
17.0 Inspection and Diagnosis—Duct Leakage .....	117
18.0 Inspection and Diagnosis—Cooling System .....	125
19.0 Inspection and Diagnosis—Heating and Cooling Ductwork Design and Airflow ...	129
20.0 Inspection and Diagnosis—Conditioned Zones .....	137
21.0 Inspection and Diagnosis—Baseload Appliances and Lighting.....	143
22.0 Analysis and Presentation Practices—Prepare For Calculations .....	147
23.0 Analysis and Presentation Practices—Conduct Billing Analysis .....	151
24.0 Analysis and Presentation Practices—Conduct Base Building Calculations.....	153
25.0 Analysis and Presentation Practices—Evaluate Ventilation Requirements .....	157
26.0 Analysis and Presentation Practices—Evaluate Improvements for Inclusion in Packages based on Both Energy and Non-energy Impacts .....	161
27.0 Analysis and Presentation Practices—Create a Customer Report .....	165

28.0	Analysis and Presentation Practices—Estimate the Cost and Proposed Price for Recommended Improvements .....	169
29.0	Analysis and Presentation Practices—Create a Customer Proposal and a Workscope .....	173
30.0	Installation Practices—General .....	175
31.0	Installation Practices—Windows .....	177
32.0	Installation Practices—Moisture Control and IAQ.....	181
33.0	Installation/Repair Practices—Combustion HVAC, Water Heater, and Appliances	187
34.0	Installation Practices—Lighting and Appliances.....	193
35.0	Installation Practices—Insulation .....	195
36.0	Installation Practices—Air Distribution Systems.....	205
37.0	Installation Practices—Cooling Systems.....	213
38.0	Installation Practices—Test-Out and Documentation.....	219
39.0	Business Practices—Assuring Quality .....	221
40.0	Business Practices—Marketing Home Performance Retrofits .....	225
41.0	Business Practices—From Leads to Home Inspections.....	229
42.0	Business Practices—The Diagnosis and Sale .....	231
43.0	Business Practices—Field Activities Infrastructure.....	235
44.0	Business Practices—On-Site Job Management.....	237
45.0	Business Practices—Job Followup Activities .....	239
46.0	Business Practices—Planning and Management .....	241
47.0	Glossary .....	245

## List of Tables

Table 1.1.	Inspection and diagnosis practices—general .....	7
Table 1.2.	Inspection and diagnosis practices—customer concern interviewing .....	7
Table 1.3.	Inspection and diagnosis practices—site inspection.....	8
Table 1.4.	Inspection and diagnosis practices—health, durability, IAQ and safety .....	8
Table 1.5.	Inspection and diagnosis practices—moisture inspection .....	8
Table 1.6.	Inspection and diagnosis practices—mechanical ventilation .....	9
Table 1.7.	Inspection and diagnosis practices—carbon monoxide .....	9
Table 1.8.	Inspection and diagnosis practices—combustion appliance zones .....	9

Table 1.9. Inspection and diagnosis practices—heat exchangers .....	10
Table 1.10. Inspection and diagnosis practices—combustion efficiency, flue inspection, HVAC & DHW .....	10
Table 1.11. Inspection and diagnosis practices—appliance venting and vent pressure .....	10
Table 1.12. Inspection and diagnosis practices—building envelope .....	11
Table 1.13. Inspection and diagnosis practices—thermal boundary .....	11
Table 1.14. Inspection and diagnosis practices—blower door test .....	11
Table 1.15. Inspection and diagnosis practices—transition zones .....	11
Table 1.16. Inspection and diagnosis practices—duct leakage .....	12
Table 1.17. Inspection and diagnosis practices—cooling system .....	12
Table 1.18. Inspection and diagnosis practices—heating and cooling ductwork design and airflow .....	12
Table 1.19. Inspection and diagnosis practices—conditioned zones .....	12
Table 1.20. Inspection and diagnosis practices—baseload appliances and lighting .....	13
Table 1.21. Analysis and presentation practices—prepare for calculations .....	13
Table 1.22. Analysis and presentation practices—conduct billing analysis .....	13
Table 1.23. Analysis and presentation practices—conduct base building calculations .....	13
Table 1.24. Analysis and presentation practices—evaluate ventilation requirements.....	14
Table 1.25. Analysis and presentation practices—evaluate improvements for inclusion in packages based on both energy and non-energy impacts.....	14
Table 1.26. Analysis and presentation practices—create a customer report .....	14
Table 1.27. Analysis and presentation practices—estimate the cost and proposed price for recommended Improvements .....	15
Table 1.28. Analysis and presentation practices—create a customer proposal and a workscope	15
Table 1.29. Installation practices—general .....	15
Table 1.30. Installation practices—windows.....	15
Table 1.31. Installation practices—moisture control and IAQ.....	16
Table 1.32. Installation practices—combustion HVAC/WH/appliances.....	16
Table 1.33. Installation practices—lighting and appliances .....	16
Table 1.34. Installation practices—insulation.....	16

Table 1.35. Installation practices—air distribution systems.....	16
Table 1.36. Installation practices—cooling systems .....	17
Table 1.37. Installation practices—test-out and documentation .....	17
Table 1.38. Business and marketing practices—assuring quality .....	17
Table 1.39. Business and marketing practices—marketing home performance retrofits .....	17
Table 1.40 Business and marketing practices—from leads to home inspections.....	18
Table 1.41. Business and marketing practices—the diagnosis and sale.....	18
Table 1.42. Business and marketing practices—field activities infrastructure.....	18
Table 1.43. Business and marketing practices—onsite job management activities .....	18
Table 1.44. Business and marketing practices—job followup activities.....	18
Table 1.45. Business and marketing practices—administrative business practices.....	19
Table 4.1. Site inspection.....	35
Table 8.1. Recording of test results.....	66
Table 8.2. Drafting tests.....	66
Table 17.1 Lighting (frequently used fixtures).....	122
Table 17.2 Exhaust fan duct condition .....	122
Table 17.3 Exhaust fan flow .....	122
Table 17.4 Appliances (primary).....	122
Table 17.5 Domestic hot water .....	123
Table 20.1. Conditioned zones .....	140
Table 20.2. Pressure mapping.....	141

## Abstract

This Volume II to the project's Final Report (*Whole House Contracting Protocols Project*, CEC-500-2007-018 VI) presents the Task 2.3 deliverable—a set of best practice protocols for comprehensive “whole house” analysis and retrofit contracting. These protocols provide a foundation of basic guidance to programs for training and supporting contractors in the field.

This volume represents a key step in standardizing the home performance contracting process and provides a foundation for subsequent refinements and corrections by the industry. The protocols also offer a starting point for a national debate and consensus-building process for helping to professionalize the industry and create a broadly accepted common ground of best practices.

**Keywords:** best practice protocols, whole house retrofit, whole house performance contracting, energy efficiency, comprehensive workscope



# Executive Summary

## Introduction

In California and the nation, the push is on to maximize energy efficiency, including taking measures to improve the energy efficiency in our homes. New homes are currently being built under initiatives such as the national Energy Star® Homes program and California's Title 24 energy code, which established energy efficiency standards for buildings to reduce California's energy consumption. Existing homes, which represent the vast majority of California homes and are typically less energy efficient than new ones, provide a major unmet opportunity for energy savings through retrofitting.

Currently, energy efficiency programs for existing homes tend to address only individual measures of concern, such as ceiling insulation or window replacement. Although such measures provide energy savings, taking a piecemeal approach fails to capture the greater energy savings and other valuable benefits of a comprehensive approach that looks at the whole house (WH) as an integrated system. That comprehensive whole house approach includes performance testing and reduction of the home's thermal load to ensure that the home's maximum potential energy and peak demand savings as well as safety, health, comfort and home value improvements are realized through thorough assessment, installation, and quality assurance.

## Project Purpose and Objectives

This project's primary goal is to develop this Best Practices Guide as a reference for contractors and sponsoring programs in California and elsewhere. It represents a key step in standardizing the home performance contracting process and provides a foundation for subsequent refinements and corrections by the industry.

## Outcomes

This report presents a set of best practice protocols for comprehensive whole house analysis and retrofit contracting to be used by contractors and home performance training programs. Already they were successfully used in a California Public Utilities Commission implementation program and adopted as the basis for a project by the U.S. Department of Housing and Urban Development (HUD) to develop a system for improving energy-related practices of all contractors nationwide. When complete, the HUD project will provide online best-practices education to tens of thousands of remodeling and repair contractors nationwide.

Additionally, the protocols encourage an active and ongoing discussion within the energy efficiency community, as well as among heating, ventilation, and air conditioning (HVAC) and building-shell improvement contractors and their professional organizations, that will further the advancement of the whole house retrofit process and help it gain wider acceptance.

## **Conclusions**

Technical and business barriers remain in the way of broad adoption of home performance contracting. Nonetheless, the best practice protocols provide a means of disseminating valuable new capabilities to contractors. Exposure to those new capabilities will encourage more contractors to consider whole house retrofitting as a model they can adopt for enhancement of their business.

The protocol set also complements emerging utility programs seeking to train and support contractors in a transition to improved energy-saving practices. Those publicly funded education and training opportunities, along with public education and contractor transition-support programs, play a vital role in preparing contractors for whole house retrofitting and gaining public understanding and support.

## **Recommendations**

*New research into homeowner motivations* is needed to provide an adequate basis for state policy refinements to assess home performance retrofit programs more fairly. Current evidence is limited but suggests that non-energy benefits unique to comprehensive home performance retrofits may be the principal drivers of investment and success.

Integrating whole house retrofitting with *green remodeling and home solar programs*, along with partnering between public energy efficiency funding programs and the California Building Performance Contractors Association (CBPCA), can serve as a strong foundation for professional identity and statewide support.

Further *technical and business training plus ongoing support* are needed to prepare contractors for home performance retrofit work, and improved benefit/cost analysis policy and tools are needed to clearly demonstrate the cost-effectiveness of such support. This specifically focuses on the bias inherent in the current Total Resource Cost (TRC) test.

Publicly funded *implementation programs will be essential* for at least several years to build both an adequate tipping-point contractor base and sufficient consumer awareness to sustain those contractors in this new business.

## **Benefits to California**

Effectively strengthening and gaining acceptance for the whole house energy performance model, along with its integration with the green building and solar energy movements, will require the emergence of a comprehensive energy-related home upgrading strategy. As this approach gains political and public support, the state will realize substantially increased residential energy savings. The reductions in home energy use and peak-period electricity demand across the state will mean greater energy security, reduced energy costs, avoidance of unnecessary investment in electricity system expansion, new skilled jobs in home improvement, and a host of environmental benefits.

Finally, homeowners and occupants will realize major non-energy benefits, such as increased comfort, safety, and indoor air quality (IAR) and resulting health improvements, as well as

savings in home repairs—all of which will increase individual motivation to invest in these improvements and thereby to create a level of energy savings otherwise lost through conventional practices.



## 1.0 Introduction—Benefits to California

This Volume II to the project’s Final Report (*Whole House Contracting Protocols Project, CEC-500-2007-XXX*) presents the Task 2.3 deliverable—a set of best practice protocols for comprehensive whole house (WH) analysis and retrofit contracting. These protocols are intended to provide a foundation of basic guidance to programs for training and supporting contractors in the field. These protocols are not “final” in the sense that best practices in this rapidly evolving field are subject both to constant refinement as well as healthy controversy among practitioners and researchers. However, they provide for the first time a comprehensive array of proposed best practices to encourage an active and continuing discussion and advancement of national consensus.

This Reference Manual complements the information provided about the protocol development process and content in Chapter 3 of the Final Report for this PIER project. Each line of the following tables represents a topic for which recommended best practices have been identified and indexed to reference sources, where available. The tables are followed by the full text of each protocol listed. The protocols make use of the same order and titling of the tables.

This project’s primary goal is to develop this Best Practices Guide as a reference for contractors and sponsoring programs in California and elsewhere. It represents a key step in standardizing the home performance contracting process and provides a foundation for subsequent refinements and corrections by the industry. The protocols also offer a starting point for a national debate and consensus-building process for helping to professionalize the industry and create a broadly accepted common ground of best practices.

### 1.1. Overview of the Protocol Set

#### ***Inspection and Diagnosis Practices***

- General Practices
- Customer Concerns
- Site Inspection
- Health, Durability, Indoor Air Quality (IAQ), and Safety
- Moisture Inspection
- Mechanical Ventilation
- Carbon Monoxide (CO)
- Combustion Zone
- Heat Exchanger
- Combustion Efficiency, Flue Inspection, Heating, Ventilation, and Air Condition (HVAC), and Domestic Hot Water (DHW)
- Appliance Venting and Vent Pressures

- Building Envelope
- Thermal Boundary
- Blower Door Test
- Transition Zones
- Duct leakage
- Cooling System
- Heating and Cooling Ductwork, System Air Flow Testing
- Conditioned Zones
- Baseload Appliances and Lighting

### ***Analysis and Presentation Practices***

- Prepare For Calculations
- Conduct Billing Analysis
- Conduct Base Building Calculations
- Evaluate Ventilation Requirements
- Evaluate Improvements for Inclusion in Packages Based on Both Energy and Non-Energy Impacts
- Create a Customer Report
- Estimate the Cost and Proposed Price For Recommended Improvements
- Create a Customer Proposal and a Workslope

### ***Installation Practices***

- General
- Windows
- Moisture Control and IAQ
- Combustion HVAC/WH/Appliances
- Lighting and Appliances
- Insulation
- Air Distribution Systems
- Cooling Systems
- Test-Out and Documentation

## ***Business Practices***

- Assuring Quality
- Marketing Home Performance Retrofits
- From Leads to Home Inspections
- The Diagnosis and Sale
- Field Activities Infrastructure
- Onsite Job Management Activities
- Job Followup Activities
- Administrative Business Practices

The remainder of this Reference Guide consists of the text of each Best Practice Protocol. These protocols are in text form, without illustrations or other contractor self-help refinements, since training organizations are expected to adapt the materials to their own preferences and local conditions.

## **1.2. Learning Objectives by Protocol**

### ***1.2.1. Inspection and Diagnosis Practices***

**Table 1.1. Inspection and diagnosis practices—general**

Maintain and utilize diagnostic equipment in accordance with manufacturers specifications.

Perform a "Whole House" investigation.

Maintain a logical sequence to the order of systems testing.

Determine probable causes and resolutions for issues and problems.

Record results and written recommendations.

---

**Table 1.2. Inspection and diagnosis practices—customer concern interviewing**

---

Involve the occupant at the beginning of the investigation.

Identify the number of occupants and appliance utilization habits for ventilation.

Ask about the structural integrity of the building.

Ask about historical or seasonal moisture issues.

Ask about systems performance.

Ask about health concerns or complaints.

Ask about occupant influence on distribution systems.

Ask about building configurations, auxiliary fuels and thermostat settings.

Collect energy use information from fuel vendors, or fuel-use records.

---

**Table 1.3. Inspection and diagnosis practices—site inspection**

- Evaluate site drainage opportunities for ground water, surface water and roof runoff.
  - Determine air quality issues that may result from building's location.
  - Evaluate solar impact on southern exposures.
  - Evaluate heating degree days (HDD) and cooling degree days (CDD).
  - Evaluate wind effect and any potential impact.
  - Identify the foundation systems present and moisture's impact on them.
  - Inspect building foundation for the effects of site design issues.
  - Inspect building frame for moisture and associated degradation.
- 

**Table 1.4. Inspection and diagnosis practices—health, durability, IAQ and safety**

- Inspect crawl space for existing or potential pollutant sources.
  - Provide a short term radon test.
  - Identify other home conditions contributing to poor air quality.
  - Compare home pollutant levels with acceptable and unsafe levels.
  - Evaluate the need for additional or seasonal fresh air supply.
  - Identify improper storage of volatile organic compounds and household chemicals.
  - Determine response options to any identified fuel leaks.
  - Evaluate any lead associated with building materials that may require handling in the course of any proposed work.
  - Inspect building for material storage that poses potential fire hazard.
  - Conduct egress evaluation and provide recommendations to customer.
- 

**Table 1.5. Inspection and diagnosis practices—moisture inspection**

- Conduct a visual inspection of the building for indications of excess moisture.
- Conduct a relative humidity test.
- Utilize a psychrometric chart to interpret potential for moisture problems.
- Evaluate the causes of any mold and mildew growth in closets, corners and remote areas of the living area.
- Evaluate the impact of humidifiers and dehumidifiers upon the indoor air quality and upon the integrity of heating/cooling appliances.
- Evaluate and control moisture sources that produce condensation on interior building surfaces.

**Table 1.6. Inspection and diagnosis practices—mechanical ventilation**

---

Identify any pollutant sources requiring ventilation as a control method.

Measure capacity of mechanical ventilation systems.

Determine ventilation requirements based on building use, size and occupants.

Determine type of ventilation system that is most appropriate.

Determine controller best suited for mechanical ventilation.

Determine proper placement of the air supply and air exhaust components of a ventilation system.

---

**Table 1.7. Inspection and diagnosis practices—carbon monoxide**

---

Establish that the house is safe.

Determine the operational range for each draft in each vented combustion appliance.

Configure the combustion appliance zone into "worst case".

Determine if there are any safety issues with the combustion appliance zone.

Identify any issues that might require immediate attention.

Identify the proper location to conduct a meaningful carbon monoxide test.

Follow mechanical operation of combustion appliances in the proper sequence.

Test drafts with the use of differential manometer.

Respond to action levels for carbon monoxide in the home environment.

Inspect ovens and ranges for CO-efficient operation.

Evaluate the positions, performance features, and operating ranges of existing carbon monoxide detectors.

Evaluate any potential for occupant exposure to carbon monoxide.

Conduct a carbon monoxide test of gas ovens and range tops.

Conduct another ambient environment carbon monoxide test.

Share results with the building's occupants.

---

**Table 1.8. Inspection and diagnosis practices—combustion appliance zones**

---

Take control of all mechanical and combustion equipment.

Configure the building and each combustion appliance zone (CAZ) for greatest potential for negative pressure within that zone.

Perform appliance operations testing.

Measure the extent of negative pressure created within the zone, under worst-case scenario.

Identify the dynamics that influence the combustion appliance zone.

---

**Table 1.9. Inspection and diagnosis practices—heat exchangers**

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Identify design specifications for a variety of heat exchangers.  
Inspect for indications of heat exchanger deterioration.  
Perform appropriate tests according to the type of heat exchanger.

---

**Table 1.10. Inspection and diagnosis practices—combustion efficiency, flue inspection, HVAC & DHW**

---

Identify design and performance specifications for combustion appliances.  
Configure the building for combustion appliance testing.  
Determine the appropriate location to collect combustion gas samples.  
Determine when “steady state” has been attained by temperature readings.  
Measure samples of combustion products and combustion gas characteristics.  
Maintain and properly utilize combustion efficiency test equipment.  
Perform a combustion efficiency test and compare results to manufacturer’s specifications.  
Measuring the temperature rise across the heat exchanger.  
Identify techniques for inspecting combustion chambers for a variety of appliances.  
Evaluate thermostat performance.  
Evaluate thermostat location with relationship to occupant comfort.  
Evaluate the benefit of installing a setback thermostat.  
Identify fuels and distribution systems used within a building.  
Maintain and utilize diagnostic equipment in investigation of fuel leaks.  
Conduct a water heating appliance evaluation.  
Identify the type and components of cooling systems.  
Provide a maintenance inspection of the cooling system.  
Identify the tools and products used and perform a cleaning of cooling systems.  
Record results of cooling system inspection.

---

**Table 1.11. Inspection and diagnosis practices—appliance venting and vent pressure**

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Identify all ventilating appliances to be tested.

---

Inspect venting system for design, maintenance and safety.  
Identify all un-vented and under-vented combustion appliances.  
Inspect appliance vent for obstructions and design.  
Inspect combustion appliance vent systems for required clearance to combustible materials.  
Provide a vent pressure test.  
Conduct vent spillage tests.

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**Table 1.12. Inspection and diagnosis practices—building envelope**

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Identify the framing style used in construction.

Determine framing techniques and characteristics incorporated into a structure.

Inspect the building envelope for continuity.

Identify the building materials utilized in establishing the building envelope, and any degradation.

Evaluate ventilation systems that penetrate the building envelope.

Determine if attic ventilation has any impact on the conditioned areas of the building.

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**Table 1.13. Inspection and diagnosis practices—thermal boundary**

---

Define and document all existing thermal boundary components.

Collect relevant building dimensions.

Perform a visual inspection on each thermal boundary component.

Conduct an infrared inspection of the entire thermal boundary.

Record results and recommendations on the attached sheets.

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**Table 1.14. Inspection and diagnosis practices—blower door test**

---

Configure the building envelope for pressure testing.

Configure the internal building configuration for pressure testing.

Identify and correct building conditions that may be problematic during pressure testing.

Select an appropriate location and install a blower door.

Conduct and interpret a blower door test.

Determine the type of test (pressurization or depressurization) best suited for the building.

Utilize a blower door in the evaluation of air sealing needs and the effectiveness of installations.

Ensure the building and systems are operational, at the completion of blower door work.

---

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**Table 1.15. Inspection and diagnosis practices—transition zones**

---

Identify all transition zones associated with the conditioned area.

Inspect key junctures of the building frame for air leakage or signs of long term air leakage.

Utilize the blower door in the evaluation of the building frame for air leakage paths.

Quantify leakage between conditioned areas and attached zones.

Establish a selected pressure difference across the air/thermal boundary.

---

**Table 1.16. Inspection and diagnosis practices—duct leakage**

---

Inspect ducts and associated areas.  
Establish ducts and zones in a testing mode.  
Configure the building and install diagnostic equipment for duct leakage testing.  
Perform and interpret a cumulative leakage test.  
Perform and interpret duct leakage to the outdoors test.  
Perform and interpret individual duct leakage tests.  
Identify air leakage sites in a forced air system.

---

**Table 1.17. Inspection and diagnosis practices—cooling system**

---

Balance zonal pressures that exceed action levels.  
Ascertain duct leakage.  
Consider duct conduction.  
Consider room-to-room air flows.  
Consider air flow through the evaporator.  
Consider refrigerant charge.  
Consider condensing unit sizing

---

**Table 1.18. Inspection and diagnosis practices—heating and cooling ductwork design and airflow**

---

Identify the components of the distribution system and provide a visual inspection.  
Evaluate the heat transfer characteristics of the heating/cooling distribution, with relationship to occupant comfort.  
Identify the basic principles of proper duct design.  
Measure airflow across the cooling coil.  
Evaluate air flow volumes with relation to recommendations.  
Identify factors affecting airflow requirements.  
Evaluate cooling load reduction options.  
Identify distribution components requiring insulation.

---

**Table 1.19. Inspection and diagnosis practices—conditioned zones**

---

Identify and configure each potential zone of the living space.  
Test the levels at which positive and negative pressures occur within zones of the building.  
Develop a pressure balancing strategy.  
Assess and address energy, health, and safety implications created by zonal pressures.

---

**Table 1.20. Inspection and diagnosis practices—baseload appliances and lighting**

---

Seek information from occupants related to baseload appliance usage and performance.

Conduct a lighting survey for efficiency considerations.

Identify and repair/replace recessed lighting fixtures that contribute to building air leakage and compromise thermal boundaries.

Conduct a refrigeration appliance evaluation.

Evaluate the use of flow restrictors and low flow showerheads.

Maintain and utilize diagnostic equipment in the evaluation of baseload systems.

---

### **1.2.2. Analysis and Presentation Practices**

**Table 1.21. Analysis and presentation practices—prepare for calculations**

---

Collect energy cost data.

Collect heating energy day (HDD) and cooling degree day (CDD) information for the related service territory.

Select a modeling tool for energy calculations.

Select a tool for energy bill analysis.

Prepare to maintain records for all testing, proposed workscope, and support documents.

---

**Table 1.22. Analysis and presentation practices—conduct billing analysis**

---

Collect utility bill data.

Determine the baseload energy use and the temperature-dependent energy use.

Calculate heating and cooling energy use for the building, normalized for the heated or cooled area.

Compare weather normalized energy use to the weather normalized energy use of similar buildings.

---

**Table 1.23. Analysis and presentation practices—conduct base building calculations**

---

Calculate the volume and surface areas of the building relevant to test.

Build a software-based building model of the home.

True-up the building model.

Calculate the correct size for the cooling/heating equipment.

Evaluate the performance of the distribution system.

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**Table 1.24. Analysis and presentation practices—evaluate ventilation requirements**

---

Determine the current and proposed pressure boundaries for connected building zones.

Translate artificially created airflow rates into natural airflow rates.

Determine the amount of cumulative ventilation required for site-specific situations.

---

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**Table 1.25. Analysis and presentation practices—evaluate improvements for inclusion in packages based on both energy and non-energy impacts**

---

Evaluate health and safety improvements.

Evaluate improvements based on comfort.

Evaluate building durability improvements.

Evaluate resource efficiency improvements.

Calculate savings for a range of improvements including energy efficiency.

Calculate the simple payback for recommended improvements.

Calculate life cycle benefit/cost relationships for recommended improvements.

---

---

**Table 1.26. Analysis and presentation practices—create a customer report**

---

Provide a description of the building's current condition.

Identify health and safety issues.

Show where energy is currently being used in the building.

Identify any incentives available.

Provide a list of improvements with a description of each.

Recommend packages of improvements based on various levels of investment.

---

**Table 1.27. Analysis and presentation practices—estimate the cost and proposed price for recommended improvements**

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Select methods in accordance with building codes and industry standards.

Define the installation standards and specifications for proposed measures.

Identify the materials and equipment specifications for each measure.

Calculate the materials and labor costs associated with proposed measures.

Incorporate the cost of overhead into the estimation process.

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Routinely compare actual profits to estimated profits.

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**Table 1.28. Analysis and presentation practices—create a customer proposal and a workscope**

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Develop a customer pricing proposal.

Present the pricing proposal to the customer.

Develop a crew workscope,

Retain information so that it can be retrieved if the customer delays implementation.

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### ***1.2.3. Installation Protocols***

**Table 1.29. Installation practices—general**

Maintain safety and cleanliness in the work area.

Provide installation instructions and standards for each measure.

Provide materials application in accordance with industry standards and building codes.

Balance zonal pressures that exceed action levels.

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**Table 1.30. Installation practices—windows**

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Select replacement windows.

Install replacement windows.

Air-seal existing windows.

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**Table 1.31. Installation practices—moisture control and IAQ**

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Identify area where molds and other biological growths appear.

Correct moisture problems in wet crawl spaces.

Set or adopt standards for practices and limits on mold-related correction work.

Monitor radon levels within a building.

Provide wet cleaning of lead contaminated surfaces.

Isolate or remove sources of pollutants (volatile organic compounds [VOCs], etc.) that may be affecting the living areas of the building.

Install kitchen exhaust fan to remove pollutants associated with the operation of kitchen appliances.

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**Table 1.32. Installation practices—combustion HVAC/WH/appliances**

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Clean burner assemblies and perform adjustments.

Clean or replace furnace air filters.

Clean and lubricate distribution fan motor, fan vanes, inspect/replace fan belt.

Clean and tune gas oven/range top burners, to reduce carbon monoxide outputs.

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**Table 1.33. Installation practices—lighting and appliances**

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Install energy efficient lighting based on performance characteristics.

Recommend energy efficient appliances.

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**Table 1.34. Installation practices—insulation**

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Insulate sidewalls with high-density cellulose.

Insulate attics and roof systems.

Insulate floor and foundation areas.

Determine the requirements and location for vapor barrier placement, with installed insulation.

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**Table 1.35. Installation practices—air distribution systems**

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Distribution system repair-redesign criteria.

Identify and correct duct leakage and conditioned air leakage into unheated crawl spaces and attic areas.

Identify and install various duct and pipe insulations.

Cooling distribution system design considerations including convective loop impacts.

Maintaining humidifiers and condensate pans in central conditioning appliances.

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**Table 1.36. Installation practices—cooling systems**

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Instrument attachment and house configuration: evaluate superheat and subcooling.  
Collect data for air conditioning systems.  
Perform superheat charging calculations: non-TXV cooling systems.  
Perform subcooling charging calculations: TXV cooling systems.  
Perform airflow calculations: evaporator temperature difference method.  
Compute actual system output.  
Evaluate evaporative cooling viability and options.

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**Table 1.37. Installation practices—test-out and documentation**

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Measure the effectiveness of air sealing.  
Provide performance testing for all installed measures.  
Provide testing of all systems that maintain interaction with installed measures.  
Document all systems testing and maintain test results.

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#### **1.2.4. Business and Marketing Practices**

**Table 1.38. Business and marketing practices—assuring quality**

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Create and use a standard job quality assurance process routinely.  
Review all test-out data and repair as needed to assure adequacy and accuracy.  
Review all job notes and comments for indications of any problems.  
Define and use a formal Dispute Resolution process.  
Instill the importance of quality assurance in all staff and subcontractors.

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**Table 1.39. Business and marketing practices—marketing home performance retrofits**

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Develop and use a consistent and effective marketing message.  
Develop marketing materials for public distribution and presentation.  
Use existing mass media channels where cost-effective.  
Create your own marketing initiatives beyond mass media.  
Make use of existing customer base for repeat business and referrals.  
Make use of existing organizations and groups as allies and branding sources.

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**Table 1.40 Business and marketing practices—from leads to home inspections**

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Respond effectively to leads.

Make clear arrangements for the diagnostic visit.

Establish a pricing strategy for the home diagnosis and evaluation

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**Table 1.41. Business and marketing practices—the diagnosis and sale**

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Perform the home inspection and develop a proposal.

Develop and employ an effective home retrofit sales process.

Close and document the sale.

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**Table 1.42. Business and marketing practices—field activities infrastructure**

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Select, set, and enforce performance standards for subcontractors.

Maintain and use a variety of testing equipment.

Develop or use existing standardized installation specifications.

Deliver product specifications, warranties, and maintenance requirements.

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**Table 1.43. Business and marketing practices—onsite job management activities**

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Keep home clean and undamaged.

Use digital photos to document work and avoid damage claims.

Communicate job requirements to the installation crew.

Follow health and safety precautions.

Use an effective standardized job closeout process.

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**Table 1.44. Business and marketing practices—job followup activities**

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Develop and use an after-job evaluation form to learn from each job.

Close out the job with good customer relations.

Follow up periodically with customer after the job is done.

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**Table 1.45. Business and marketing practices—administrative business practices**

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Define business model to be used and develop business plan for the transition.

Secure adequate funding for cash flow management.

Provide training and continuing learning opportunities for staff.

Provide support and incentives to motivate and keep quality staff.

Develop professional and business relationships and access to knowledge.

Create supporting processes and activities.

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### **1.2.5. *Best-Practice Protocols***

The remainder of this Manual presents the full text of all protocols in the order listed in the tables above.



## **2.0 Inspection and Diagnosis—General**

### **2.1. Scope**

The inspection process involves a multitude of diagnostic tests and observations, the order of which is left to the discretion of the inspector. However, there are several situations where the outcomes of diagnostic tests are dependent on the order in which testing is performed. It's important to ensure the accuracy and comprehensiveness of the inspection process. Test results are soon forgotten without detailed documentation, so general recommendations are provided here to help assure that records of test conditions and test results are formatted in a useful and standardized manner. General suggestions are also made to organize the inspection for efficiency of time. Safety-related inspections should always be performed first.

### **2.2. Tools and Materials**

(See related specific diagnostic protocols.)

### **2.3. Procedure**

#### ***2.3.1. Maintain and Utilize Diagnostic Equipment in Accordance With Manufacturer's Specifications***

The equipment used in building diagnostics has been developed to meet the specifications identified by the manufacturer—but only when the equipment is used in accordance with manufacturer's requirements. It is important that the inspector read the literature that accompanies equipment, and refer to equipment manuals routinely.

- All product literature should be copied into a handbook that accompanies the inspector to the job site. Original literature should be maintained in the business office for reference, whenever needed.
- Inspectors should be totally familiar with the operator's manuals, which not only give instruction as to the proper equipment use, but also provides important warnings on equipment misuse.
- Equipment care and calibration is critical to accuracy. Follow manufacturer's care and calibration schedules. Third party calibration may protect you in issues of liability. Know your equipment. Flow hood manufacturers say they are accurate to 3%, but can be 30% off.
- Equipment must be used only for its intended purpose, to assure accuracy of diagnostics and to maintain equipment in good working order.
- Equipment capabilities and limitations are usually defined in the equipment specification standards.
- Equipment may contain or require the use of chemicals. All chemical compounds found on the job site require a Material Safety Data Sheet, in accordance with Occupational Safety and Health Administration.

### **2.3.2. Perform a Whole House Investigation**

A whole house investigation requires the inspection and testing of the building systems for design, efficiency and interactions that may exist between individual systems. For the inquisitive inspector, it's like being a detective—since the issues may not be immediately obvious, and you may have to solve problems by deduction. Each protocol procedure may be impacted by various conditions found on site. At a minimum, the whole house inspection should include:

- Pre-arrival Tasks
- Home Owner Interview
- Site Inspection
- Combustion Appliance Safety Testing
- Envelope Tightness & Blower Door Testing
- Ventilation, Moisture & IAQ
- Insulation Performance
- Space Heating Equipment
- Cooling Equipment
- Air Flow and Duct Leakage
- Appliances and Water Heating
- Lighting

### **2.3.3. Maintain a Logical Sequence to the Order of Systems Testing**

It is best that the suggested order be followed for building testing, to optimize testing time and to help make sure that portions of the inspection are not accidentally omitted. The building report should be organized to help facilitate the inspection process.

Some diagnostics have an urgency to identify safe environments for the inspector, and certain diagnostics are more revealing if they are placed in an order with other complimentary diagnostics (for example, air distribution analysis should follow leakage testing).

- The initial occupant interview should be conducted at the beginning of the building inspection. This may provide critical information that will facilitate the inspection.
- All combustion appliance and combustion appliance zone testing should be conducted just after the occupant interview. If there is a CO or spillage problem, it should be identified before the inspector spends any length of time in the building.
- Carbon monoxide checks of the living space and attached zones (i.e., garages, combustion appliance zones) should be conducted as soon into the site visit as possible. This assures the inspector that hazardous conditions do not exist prior to testing.
- a) Duct leakage testing that requires the assistance of a blower door should immediately follow the blower door test. The house and equipment configuration is similar and the

testing conditions are already established. Pressure pan and flow hood need to be included as well.

- b) Infrared imaging of thermal boundaries to identify conduction issues should *precede* any pressure testing, and be completed with the building in *as static* a condition as possible. But infrared imaging to locate air leakage paths should *follow* pressure testing of the building. The differences identified between the two images are most likely related to air leakage path that penetrate the thermal boundary.
- c) Distribution analysis should follow leakage testing—since the house, testing equipment and ductwork are already configured.

#### **2.3.4. Determine Probable Causes and Resolutions For Issues and Problems**

It is quite likely that the home performance inspection will be the only comprehensive investigation of system interactions ever to be performed on the building. Therefore, identifying existing and potential problems is especially important.

- Look at the general conditions and maintenance of mechanical equipment. Unserviced appliances may indicate something more about the responsibilities that occupants have (or can expect to have) toward home systems in general.
- Every problem has a cause. Sometimes the source of a problem is obvious and sometimes the easy and obvious assumption is not correct. The idea of the “whole house” inspection is that assumptions are verified through comprehensive observation and testing.
- Systems interactions exist everywhere, and it is only through a methodical approach to analysis that the definitive conclusions can be reached.
- Every problem has a solution—but can the inspector identify the options and select the best solution in the context of the occupants health (and fiscal) requirements? It is important for an inspector to understand material and installation options, and to stay current with developing technologies.
- Pay attention to the subtle things like dust tracks, humidity, smells, 1 Pascal of pressure, 1 in<sup>2</sup> of attic bypass, etc. The diagnostic equipment carried by home performance inspectors is expensive because it is accurate, durable and sensitive. Use it to its greatest potential.
- Access all areas of the building, even if access is difficult, such as behind kneewalls, attic areas without access, crawl spaces and attached building zones.
- Maintenance of building systems is always required, and customer education is always part of the resolution.

### **2.3.5. Record Results and Make Recommendations**

Use standardized building report forms to document findings, diagnostic test results and testing conditions.

- Using a standardized report will prompt the inspector to the proper order in which to conduct the inspection and will help assure the inspection is comprehensive.
- Never leave spaces blank on the standardized building report. This can cause confusion as to whether testing was not completed because of an oversight, testing was not possible under existing conditions or that tests were not applicable. Leave a logical trail of notes that you can trace back if necessary.
- A standardized report will assist in the recall of information, over a long period of time.
- A standardized report will serve as the initial building benchmark, by which outcomes can be compared.
- A standardized report with recommendations will serve as evidence in the defense of the inspector, should a liability claim result.
- Diagnostic results should accompany the recommendations and proposal report given to a customer. This increases the value of the service to the customer and differentiates a home performance inspection for a typical estimate.
- Written recommendations are necessary for customer decision-making and customer education as well.

## **3.0 Inspection and Diagnosis—Customer Concern Interviewing**

### **3.1. Scope**

One of the most revealing sources for information on a building's performance issues is the discussion or interview with the occupants. It is important to know occupant expectations when determining the scope of home performance services. Personal experiences with the building and its systems can provide key insights to building performance problems. It is especially difficult to factor in seasonal characteristics when the inspection isn't taking place during that season, and lifestyle issues also weigh into factoring important home performance targets. Occupant information and occupant concerns can provide the basis for a meaningful inspection.

### **3.2. Tools and Materials**

Pad and pencil.

### **3.3. Procedure**

#### ***3.3.1. Involve the Occupant at the Beginning of the Investigation***

The beginning of the investigation is the most important time to involve the occupant in a discussion that explains home performance services, identifies any customer concerns or issues, and begins the establishment of a trust relationship. Many contractors feel that sales are made or lost within the first few minutes of this interaction. Beyond building performance issues, occupants and customers want most to know that they have employed a professional that is knowledgeable, respectful and trustworthy.

- Identify who you are, and what a home performance service represents in terms of energy use and return on investment.
- Explain the investigation process and alert the occupant to the potential for noise, as well as house configuration needs and the time required.
- Inquire into the length of time a occupant has lived at the current address. This will help identify a occupant's familiarity with seasonal long-term issues and also to correlate fuel usage records with the appropriate occupant.
- Seek permission from the occupant to access all areas of the building, including closets, cabinets and personal areas.
- Seek permission for cutting new accesses into areas that are not accessible, i.e., kneewalls, attics, and for drilling or removing building materials for inspection purposes.
- Invite the occupant to participate in areas of the inspection and witness the diagnostics procedures.

### **3.3.2. Identify the Number of Occupants and Appliance Utilization Habits for Ventilation**

Building ventilation rates are based on industry standards for the number of occupants, the size of the building, and an allowable lower limit. The largest of these three calculated numbers should be used as an initial target. However occupants may use the building in a way that provides reason to amend targeted ventilation rates.

- Determine number of occupants in the building (seasonal and full time). Situations do arise where a large number of people will be occupying a small home or apartment, or where a sole individual occupies an entire building.
- Determine if the entire conditioned area is utilized through space conditioning seasons. Sometimes, an elderly couple may no longer use the 2<sup>nd</sup> floor living space, or rooms that have been difficult to condition have been vacated.
- Determine if unvented combustion appliances are being used within the building. Although gas ovens and ranges are acceptable with proper point source ventilation, unvented appliances of any other type are not legal in the state of California.
- Look for an unvented clothes dryer. Dryer exhaust should never be captured for indoor heating or humidification.
- Identify occupant use patterns for existing ventilation systems. The presence of mechanical ventilation does not imply the proper use of ventilation. The frequency of range/and oven ventilation, as well as bathroom exhaust ventilation, should be identified by occupants.
- Determine if hobbies, crafts or sporting activities are contributing to potential pollutant sources. Combustible fuels, lead solders, plastic weld, swimming pool chemicals, and fine dusts often accompany craft activities. Point source ventilation should be considered.
- Look for the storage of volatile organic chemicals, agricultural supplies, construction materials, etc. Chemicals associated with adhesives and highly volatile construction materials, laundry supplies, insecticides and herbicides should be stored in air tight containers when possible and storage areas should be ventilated to the outdoors. Where garages are the storage location, it may be necessary to maintain a negative pressure in the garage with reference to the house.

### **3.3.3. Ask About the Structural Integrity of the Building**

Excessive moisture from internal and external sources has the ability to weaken the structural integrity of building materials and to cause unpleasant odors and health concerns for the occupants. Examine areas in the vicinity of moisture sources for signs of structural degradation.

- a) Inquire about any history concerning the replacement of structural materials or mechanical components. Inquire into history of remodeling or replacement of building materials.

- b) Examine sill beam areas for signs of capillary action from the foundation.
- c) Examine appliance zones, laundry and bath areas for peeling paint, wood decay, sheetrock damage, odors or visual molds and water spotting.
- d) Examine the roof deck from within the attic. Moisture sometimes manifests into problems in areas remote to the source, especially in colder climates. Look for mold growth, water staining or high moisture content of framing members (above 15%).

#### **3.3.4. Ask About Historical or Seasonal Moisture Issues**

The occupants may be able to identify seasonal issues that are not obviously apparent in the current season. They may also be able to identify building repairs made to correct moisture degradation.

- Inquire as to the presence of any seasonal moisture problems, including condensation on windows, visible moisture on foundation systems, corrosion of combustion vent systems, seasonal odors.
- Inquire as to the timeframe of last interior and exterior painting. (Painting may have been a response to moisture deterioration or water staining.)
- Inquire as to the use of humidifiers and dehumidifiers in response to excessive moisture or dryness problems, and any regular use of humidifiers and dehumidifiers.
- Inquire into the use of unvented combustion appliances for seasonal space heating.

#### **3.3.5. Ask About Systems Performance**

The occupant may have a good deal of information and experience with systems performance, especially if they have occupied the building for any length of time. They may have even participated in the renovation of areas of the building or contracted for systems repairs and replacements.

- Inquire about any comfort issues or complaints the occupants may have.
- Inquire into any upgrades made to thermal boundaries.
- Inquire as to the seasonal temperature setting within the building and the use of setback thermostats. If setback thermostats are not presently in use, inquire as to whether occupant would consider using automatic setback devices.
- If low-flow shower heads are not in use, would the occupant consider the installation of such devices?
- Inquire about service agreements and maintenance schedules for mechanical equipment, and if mechanical equipment has been replaced recently.

### **3.3.6. Ask About Health Concerns or Complaints**

It is important to identify any health complaints the occupant may have that are potentially building-related. It can be difficult to discern between what may be building-related and what is not, but identifying patterns in health complaints may be indicative of building-related illnesses.

- Do any occupants smoke indoors?
- Do any family members suffer from respiratory distress such as asthma?
- Do respiratory complaints ever appear on a seasonal basis?
- Do respiratory complaints seem to correlate to time spent in the building? Do symptoms seem to diminish with time away from the building?
- Are unvented appliances ever used for space heating?
- Has radon testing ever been conducted on the building? If so, what were the results and test dates?
- Have medical professionals made recommendations for modifying or conditioning the building?

### **3.3.7. Ask About Occupant Influence on Distribution Systems**

A reasonably balanced distribution system can become unbalanced and less efficient through normal occupant interaction. Look for opportunities to improve comfort and efficiency through improving distribution balancing, convection, and by providing occupant education.

- Are supply and return air registers unobstructed by carpeting, throw rugs, draperies and furniture?
- Do occupants understand the importance of return air registers, or are they just seen as drafty?
- Are balancing dampers properly positioned to suit the occupant's comfort demands? Balancing dampers at the registers should not be used for balancing noise.
- Do occupants routinely close doors to rooms that contain supply registers only?
- Do occupants routinely change or clean filters associated with air distribution systems? (Do the occupants know where the filters are without prompting?)
- Have registers to certain areas of the building been intentionally closed by the occupant?

### **3.3.8. Ask About Building Configurations, Auxiliary Fuels, and Thermostat Settings**

Building occupants habit patterns may influence fuel usage in ways that may not match the building model of space conditioning. Examples of this might be a frugal occupant that heats or cools only a small amount of space, or one who uses thermostat settings that vary from the assumed settings for heating and cooling. To place the actual fuel use into proper perspective, it is important to ask the occupants the following;

- What are the common thermostat settings for summer cooling and winter heating?
- Are setback temperatures used for heating or cooling?
- How many hours a day is the building occupied, and what are the usual hours?
- If summer cooling is provided by room-sized portable AC units, how many rooms are conditioned?
- Are supplemental fuels used to provide seasonal heating? If so, for what rooms?
- If setback thermostats are not in use, would the occupant consider the installation and use of setback thermostats?

### **3.3.9. Collect Energy Use Information From Fuel Vendors, or Fuel-Use Records**

Actual fuel usage history of a building is a powerful tool for validating the building model, evaluating opportunities for real energy savings and evaluating the results of installed measures. When energy use of a building has been normalized for temperature, (Heating Degree and Cooling Degree Days) and for building size (square feet of conditioned area), then an energy *factor* for the building can be derived. As important an evaluation tool as this is, it is often not factored into the building evaluation and opportunities are lost for determining the real effectiveness of installed measures. Most fuel vendors consider this information to be confidential and are reluctant to release information without a signed authorization from the occupant.

- Does the occupant have relevant and complete fuel-use records, covering a period of at least one year?
- Will the occupant sign an authorization for the release of fuel-use records?
- Are there auxiliary fuels that should be included in fuel-use data?
- Collect computerized or electronic printout for all fuels used in the building for heating, cooling and baseload use from the appropriate vendors.



## 4.0 Inspection and Diagnosis—Site Inspection

### 4.1. Scope

The building site may influence the performance of several building systems, including space heating and cooling, structural integrity, and indoor air quality. An evaluation of site considerations may identify ways in which building integrity, occupant comfort, and safety can be improved, while taking advantage of potentially free heating and cooling sources. In this inspection, you will identify the environmental factors that can impact the performance of "whole house" systems operations. Start by consulting with the occupants of the building about any known issues or problems.

### 4.2. Tools and Materials

A "bubble" level, directional compass, pin type moisture meter, radon monitor, carbon monoxide sensor.

### 4.3. Procedure

#### ***4.3.1. Evaluate Site Drainage Opportunities for Groundwater, Surface Water, and Roof Runoff***

External moisture sources are a primary cause of internal moisture problems. Surface water and run-off from driveways, parking lots, sprinkler systems, and large watersheds should be controlled by surface grades or by diversion ditches and tile lines designed to direct water away from the building. Perforated drain systems at the footing of the building may be effective at keeping water away from the foundation, but few older buildings incorporate this strategy. Where a footing drain is incorporated, it is usually distinguishable by a visible termination at grade somewhere away from the building.

Water runoff from roof systems will be deposited at the foundation of the building unless gutters and downspouts are used to direct this runoff away from buildings. Inspect these systems for proper pitch of 1" per 10' of run and for indications of leakage at connecting joints. Downspouts should be extended far enough away from the building to assure water does not run back toward the foundation. Document any exterior conditions that are to the detriment of the building.

#### ***4.3.2. Determine Environmental Health Issues that May Result from the Building's Location***

Poor indoor air quality is usually thought to originate from inside the building. But external air, water, and soil may provide pollutant sources that also compromise indoor air quality. Homes located in the proximity or downwind from industries or transportation routes may be subject to high levels of particulates and carbon monoxide. In fact, the air exchange between a building and the ambient determines the baseline level for such pollutants.

1. Use a CO detector to test for carbon monoxide. If the ambient level of carbon monoxide is measured at 15 parts per million (ppm), it is likely that the interior of the building will have a baseline measurement of 15 ppm as well. Exterior sources must be taken into

consideration during a building evaluation to determine if there is a source of carbon monoxide from within the building (indoor levels minus outdoor levels = indoor source strength). Test first for carbon monoxide outdoors—with accurate and calibrated equipment—prior to conducting any indoor measurements.

2. Use a radon tester to test for radon in closed buildings and at building levels in contact with the ground. Radon is generally found in regions which have been identified by the Environmental Protection Agency (EPA). By referencing available EPA maps, a determination can be made that testing homes for radon gas is appropriate. Time weighted, short term radon testing is recommended whenever buildings are located in geographical areas where radon is probable. Test results indicating 4 pico curies per liter or greater should warrant additional long term testing.
3. Consult [www.scorecard.org](http://www.scorecard.org) to determine if a building is located on or near an identified brown field. All too often, housing developments are constructed on land that once served as landfill for local industry. Many of these sites have been identified by EPA and Environmental Defense, and have been mapped by zip code. In such situations, air sealing and ventilation strategies may be important home performance considerations, especially if there are occupant complaints.
4. Document any identifiable air, water, or soil pollutants and the results of carbon monoxide ambient testing and radon soil gas testing.

#### **4.3.3. Evaluate Solar Impact on Southern Exposures**

The southern exposure of a building is subject to solar radiation that may provide British thermal units (Btu) for winter space heating, especially if window are oriented to the south. The lower altitude of the sun in the wintertime allows solar energy to pass through vertical windows, optimizing solar gains. Landscaping techniques to take advantage of solar gains in the winter routinely include placing foliage that does not block solar entry through south facing windows, such as deciduous trees that loose leaves in the winter, on the south side of the building.

1. Summer shading of the south side of the building is usually desired to control solar gains, especially through windows. The deciduous trees described above will help to shade the southern exposure and prevent some unwanted solar gains during the cooling season. As the altitude of the sun increases during the summer, roof overhangs and awnings are also an effective way to reduce solar gains through window.
2. If the building is located in a predominately cooling region (air conditioners are run more than heating systems) window selection for units facing south should be based on a low Solar Heating Gain Coefficient and a low-emissivity (low-e). There is no practical field test to determine window properties. If the brand and model is known, refer to the National Fenestration Rating Council (NFRC) performance data. Solar gains and losses through windows can be controlled with window insulation or drapery. This will also have the benefit of controlling the radiant temperature of windows and improving occupant comfort in both winter and summer.

#### **4.3.4. Evaluate Heating Degree Day and Cooling Degree Days**

One important measure of a building's integration into the building site is in looking at historical fuel data for an average year. Take a given year and identify any months of the year when heating/cooling is NOT required—whatever is left is “space conditioning” requirements.

1. Space conditioning—Average seasonal temperatures vary from region to region and can vary within a particular region, due to geographical characteristics such as elevation and proximity to large bodies of water. With accurate weather data for an area, the energy usage of the building can be normalized for temperature. This forms the basis of equation to determine the Btus required per HDD or CDD for space conditioning. Space conditioning Btus are then divided by HDD/CDD for a given year.
2. This is a third-party validation of the building's upgrade requirements. Having this information is an important clue to building performance prior to—and at the completion of—any proposed remediation project. Building analysis software can compare the modeled energy performance to the actual performance for the purposes of determining model accuracy and to evaluate the true savings benefit customers realize.

#### **4.3.5. Evaluate Wind Effect and Any Potential Impact**

Wind has the effect of increasing the air leakage rates on buildings in both the heating and cooling seasons. This is usually not desirable in either case. It is important to assess wind impact on the building for two reasons:

- To project the average seasonal air leakage rates (use Lawrence Berkeley National Laboratory [LBNL] standard, or an “n” factor for a typical building at 50 Pascal).
  - To recommend strategies that will minimize wind impact.
1. The National Oceanic Atmospheric Administration maintains mean wind speed for areas of the country and this data may be helpful in your assessment. However, this information may not reflect the true conditions of the site, which is more dependent on elevation and obstructions on the prevailing windward side of the building, that is, other buildings and trees. Where wind barriers would be helpful in diminishing wind impact on buildings, trees are most commonly placed at a strategic distance from the building. Generally speaking, the height of the barrier is 1/10th the distance of wind buffering. A 40'-tall grove of trees will buffer to a distance of 400' on the leeward side.

#### **4.3.6. Identify the Foundation Systems Present and Moisture's Impact on Them**

1. The foundation system that connects the building to the earth may consist of a basement with sidewalls and a slab, a slab on grade or piers that elevate the building above the grade. In pier construction, a crawl space will likely be present, either open to ambient or closed. Even dry soil contains and releases quite a bit of moisture into the conditioned

space via the “stack effect.” Moisture and infiltration move from the crawlspace to the home due to “the stack effect.” Many buildings utilize more than one type of foundation and this should be documented. Also, determine the materials used in the construction of the foundation and whether the foundation is vented or unvented. Try to determine if slabs—either on grade or below grade—were installed on a gravel bed or in very porous soil. This will remediate the potential for moisture problems and assist in the design of a radon control system should one be required.

2. Where moisture from the ground or exterior of the building presents problems, two things must be accomplished.
  - o The exterior source of moisture must be mitigated, and
  - o The foundation components must be dried.
3. Look for visual indicators of long-term moisture issues. Spalling of concrete, water staining, mold growth, visual dampness and discoloration are all affirmations that moisture is problematic. Using a moisture meter may indicate high levels of moisture under the conditions of the investigation, (above 15% moisture content) but it is possible that foundations with ongoing moisture problems may not be moisture loaded at the time of the inspection. This is a very time-sensitive inspection.
4. Determining the best solution for controlling an exterior moisture source may be as simple as repairing a gutter or downspout or as complicated as major grade excavation. Therefore be certain that the source has truly been identified and the solution is well planned before proposing expensive improvements.
5. Cleaning up crawlspaces and eliminating crawlspace ventilation can be important. Crawl spaces should be cleaned out with a layer of 6-mil poly laid down. This will improve indoor air quality in the house.
6. Determine if once the moisture source has been mitigated; determine how the drying of foundation components will occur. If the existing moisture must dry to the interior, will drying be rapid enough to not cause additional problems to the building interior.

#### **4.3.7. Inspect Building Foundation For the Effects of Site Design Issues**

Determine if any component of the foundation has been damaged to the point where it is structurally unsound or compromising the support for the building. Spalling or crumbling of masonry materials indicates moisture damage, while large cracks or movement in walls may indicate shear forces from the exterior soils. Site pressures can intersect with remodeling activities to put undue strain on a foundation.

1. Inspect the exterior of the foundation for signs of insect infestation that will not necessarily affect masonry materials, but may threaten sill beams and wood members.
2. From the inside, inspect for insect damage by looking for pinholes or fine wood dust in structural supports.

#### **4.3.8. Inspect Building Frame For Moisture and Associated Degradation**

Exterior moisture that is transferred to the masonry foundation may find its way to the wood framing members by capillary action. In new construction, capillary breaks are installed to prevent the movement of moisture from the masonry to wood framing, but older building often lack this detail.

1. Probe wood framing that is in contact with foundations, with a jack knife or awl to identify areas of dry rot. Visually inspect wood framing members for water staining or discoloration and use a pin type moisture meter to measure the moisture content of framing materials. Results above 12% moisture content indicates potential for wood decay.

**Table 4.1. Site inspection**

<b>Item</b>	<b>Inspector Comments</b>
Site impact	
Site grading for water diversion	
Roof / drain / gutter systems	
Exterior and building envelope	
Exposed ground in basement or crawlspace	
Geographical impact	
HDD / CDD	
Solar impact	
Building orientation	
Windows and physical obstructions	
Summer shading opportunities	
Wind impact	
Wind barriers	
Roof peak and chimney termination	
Local environmental issues	
Elevation	
Air contaminants	

Geological radon issues	
Other Data Collection	
Number of rooms	
Number of occupants	
Square footage of conditioned areas	
Outdoor temperature	
Wind speed	

Notes:

## **5.0 Inspection and Diagnosis—Health, Durability, Indoor Air Quality, and Safety**

### **5.1. Scope**

The intent of this inspection is to identify any existing conditions that pose a risk to building occupants, in the hopes that remediation strategies can be included in the home performance services.

It is also important to identify any potential IAQ problems that could be compounded by home performance services that alter airflow rates and patterns within the building.

People have long thought that poor air quality was an outdoor problem caused by industrialization or automobile emissions, and that their homes were reasonably safe. Evidence now points to a potential for air quality issues originating from within the buildings. Poor indoor air quality is responsible for several thousands of chronic illnesses annually within the United States. There's no way to really know the number of people who experience noticeable responses to poor indoor air quality and do not seek medical attention, or the number of times the medical community fails to associate a reported complaint with an indoor air quality issue. The goal of this inspection includes looking for any significant indoor air contaminants.

### **5.2. Tools and Materials**

Combustible gas detectors, "alpha trac" radon test canisters, publication of *Protect your Family from Lead in Your Home*.

### **5.3. Procedure**

#### **5.3.1. Inspect Cellar/Crawl Space For Existing or Potential Pollutant Sources**

Basements and crawl spaces are generally unoccupied areas between the living space and the ground. Although they are not intended to be living space, they often contribute air to the living space and should be inspected for potential pollutant sources. Typical sources of pollutants are the earth itself, mechanical equipment, stored and construction materials.

1. Contact with the earth provides a pathway for both moisture and soil gas to enter the building. Radon soil gas testing should be conducted periodically in any building that's in contact with the earth unless two or more buildings in the immediate area have been tested and proven not to have a problem. This radioactive gas can only be detected with specialty equipment or with specially designed testing mediums that are placed in the basement or crawl space zones for a measured amount of time and then forwarded to a laboratory for analysis.
2. An inspection for moisture should include a visual identification of water staining, masonry deterioration, wood decay, and oxidation of metals. If any of these are evident, you should conduct further testing of moisture content in the building materials and also an examination for the sources of moisture.

3. Mechanical equipment located in basement and crawl space areas may produce excessive amounts of moisture under in the following conditions: laundry centers rooms that are not properly ventilated to the outdoors, combustion appliances with improperly designed or faulty venting systems, passive and active ventilation systems intended to maintain airflow in the zone and forced air distribution systems that have leaks on either the supply or return side, in the zone.
4. A fuel leak inspection should be conducted along any fuel line and around any fueled appliance located in the basement or crawl space area. Combustible gas detectors should be used as they provide for sensitivity far superior to most people's sense of smell. When natural gas, propane or fuel oil leaks are located, repairs should be made immediately. Un-repaired leaks pose a fire danger and potential explosive danger.
5. Storage of home, lawn and garden chemicals often can be found in basements and crawl spaces. Many people feel that this is preferable to keeping such chemicals in the living area of the building. Because of building pressures, air leakage, distribution systems, etc., this storage is often just as unsafe. When potentially dangerous chemicals are identified as improperly stored, look for alternative storage techniques and areas, preferably well away from areas that interact with the living space. Chemicals should at least be well-labeled, kept in airtight containers and secured in cabinets that are inaccessible to children. Old and outdated chemicals should be disposed of in accordance with local environmental regulations.
6. Construction materials may contribute dusts and particulates to the air in buildings, and sometimes basements and crawl spaces contain components of hydronic heating systems that were insulated with asbestos materials. Other potentially dangerous construction materials include fiberglass, rockwool, and urea formaldehyde-based materials, all of which disintegrate to some extent with age and can become airborne. When these materials are suspected in areas of the building, it is best to leave them as undisturbed as possible during the building inspection. Most generally they are either removed or contained by professionally trained remediation specialists. Building occupants should be advised to not disturb dusts associated with these materials and to not regularly venture into areas of suspected particulates.

### **5.3.2. Provide a Short-Term Radon Test**

Action-level radon exposure is quite rare in California, but analysts should be aware of the locations of greatest concern. Detailed information on California exposure levels by county and smaller areas can be found online at this URL: <http://www.epa.gov/radon/zonemap/california.htm>

Short-term radon testing can identify an average level of exposure over a given period of time. The amount of time can vary from a few days to a few weeks, but the season for radon testing and the configuration of the building during the test are quite important. If short-term testing identifies a level of radon above the EPA "action level" (of 4 pico curies per liter), then long-term testing should be conducted to verify the initial findings.

Testing should be conducted during the period from late autumn to early spring. During this period, the soil conditions are more likely to direct radon toward building foundations, and homes are more likely to be sealed up in winter conditions.

1. Configure the home for testing by placing it in the winter mode, with all primary windows and doors closed.
2. Place short-term radon canisters (charcoal) low in the building. If there is no basement, then “alpha trac” test canisters should be strategically placed on the first floor of the home. They should remain undisturbed from a few to several days in areas not exposed to drafts.
3. These canisters should then be sealed, labeled with information concerning the location and exposure time, and sent to a radon testing laboratory. Results should be returned within a few days. Findings above 4 pico curies per liter will warrant additional testing with longer-term exposure to test canisters.

### **5.3.3. Identify Other Home Conditions Contributing to Poor Air Quality**

Compromised air quality can be found in all types of buildings and in both new and old construction. There may be specific clues that identify the greatest potential for sources of air pollutants.

1. Air generally moves from the crawlspace into the home naturally due to “the stack effect.” Ask the occupants about any symptoms of bad air coming from crawlspaces.
2. Volatile organic compounds refer to a wide group of carbon-based compounds that diffuse readily into the air. They include cleaners, deodorizers, solvents, wood finishes, insecticides, and are found in many of the household products readily purchased for the home. VOCs are also a major component in many building materials, including plywoods, oriented strand board (OSB), underlayment, fiberglass insulation, cabinetry, PVCs, and plastics. New homes and newly remodeled homes are more likely to have higher levels of VOCs. New modular and manufactured homes are still more likely to have higher levels of VOCs—especially formaldehyde—as a result of the pressed board and particleboard used in the construction. New construction may require air exchange rates higher than 0.35 air changes per hour until VOC levels have dissipated.
3. Houses built prior to 1978 are likely to contain lead-based paints. Exposure to lead can cause nerve and organ damage in humans, and lead is especially dangerous to children. Lead paints can be identified on-site with a sophisticated x-ray fluorescence analysis. In the absence of analysis, federal regulations require that any paint being disturbed in homes built prior to 1977, be handled in a lead safe manner. In addition, federal law requires any contractor to provide specific EPA information on lead paint to building owners/occupants.
4. Any home utilizing fossil fuels or solid fuels are more likely to experience carbon monoxide levels in ambient air, especially if unvented combustion appliances such as

ovens, ranges and fireplaces are in use. If fossil fuels or solid fuels are in use, carbon monoxide detectors should be located through the building (at least one on each floor).

5. Older homes that were designed with steam or hot water heating systems often utilized asbestos insulation for insulating the boiler and distribution pipes. As asbestos becomes friable or is improperly handled, microscopic dusts become airborne and can be inhaled by building occupants. Where it is suspected that asbestos has been used within the building, it is best to not disturb it. Removing asbestos can create air quality problems and is usually against the law. Encapsulation is an effective strategy in dealing with asbestos, however this should be done only by licensed asbestos handlers.
6. Dusts and particulates found in the living space—regardless of their source—can compromise IAQ, and should be cleaned up on a regular basis. Many well intentioned building occupants either sweep or vacuum the living space and succeed in spreading dusts around the building with their actions. It is recommended that homes use HEPA filtering vacuum systems. They are readily available for home use and are much more effective in capturing fine dusts and particulates.

#### **5.3.4. Compare Home Pollutant Levels With Acceptable and Unsafe Levels**

Pollutant levels may be evaluated as part of the home performance service, or may have already been tested by the building owner, based on previous health concerns, community-based programs, or general curiosity.

1. Where analytical testing has been conducted, the results should be compared to local, state and federal guidelines established as action levels and appropriate responses considered for pollutants found in excess of recommended action levels.
  - There is no established level of lead that has been deemed to be safe or acceptable in the home.
  - There is no acceptable or deemed safe level of asbestos in the home environment.
  - There are no established acceptable or tolerable levels of mold in buildings because mold's ability to grow exponentially (in only a few hours) makes any measurement meaningless.
2. If longer term testing indicates radon in the living space exceeds the EPA action level of 4 pico curies per liter, then a radon reduction strategy should be considered, especially if children live in the home. Radon mitigation is considered successful when measured levels are maintained below 1 pico curie per liter.
3. Carbon monoxide levels in buildings should never exceed 9 ppm in the living space, 50 ppm in the vent of a gas oven or 100 ppm in the exhaust vent of a vented combustion appliance. When measured levels exceed these amounts, appliance servicing should be performed in an attempt to reduce or eliminate carbon monoxide production.
4. There is no particular level of volatile organic compound that is considered safe, and for people who are chemically sensitive, any measurable amount may cause respiratory

distress, severe headaches, or neural disorders. Formaldehyde is considered a carcinogen at levels of 1 part per million.

### **5.3.5. Evaluate the Need For Additional or Seasonal Fresh Air Supply**

The recommended airflow rates for buildings—as proposed by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)—are based on the need to maintain clean, fresh, odor-free air for the occupants, while providing a level of energy efficiency. There are situations where the temporary suspension of the recommended airflow rates are in the best interests of the building occupants. These are situations for example, when elevated levels of indoor air pollutants require augmented ventilation to reduce pollutant strengths.

1. New construction or remodeling efforts may often incorporate green masonry or concrete, meaning that the vast amount of water used to formulate concrete has not been given sufficient time to evaporate from the concrete before the house is enclosed. In almost every new home including the use of green concrete, a drying time of one year should be given to the slab, foundation walls, masonry fireplaces, etc. allowed before the house is sealed and the ventilation rate of 0.35 air change per hour is established. For the first year after construction, when the outdoor air is dryer than the interior, the ventilation rate for the building should be doubled to 0.7 air changes per hour, unless mechanical dehumidification has been successfully used to dry out the building materials.
2. New construction that incorporates remodeling efforts that incorporate significant amounts of building materials containing volatile organic compounds (as found in new carpeting, cabinetry, wood finishes, particle board, linoleum, etc.) should have ventilation increased to between .5 and .75 air changes per hour for the first year after construction. This ventilation should be continued even during times when the exterior air is more humid than the interior air. This is because VOCs tend to exude gas more readily during humid conditions - and increased ventilation is required to move these gasses from the building.
3. Carbon monoxide production from ranges and ovens should be ventilated from the living space as directly as possible. This can be done with a localized fan established to move 50 on a cubic feet per minute (cfm) continuous basis, or with a hood type fan sized to move 40 cfm per linear foot of range when the range is located along a wall. A 36" wide range located on a wall should be provided a minimum of 120 cfm. If the range/oven is an island model, the minimum of 50 cfm per linear foot should be provided. The 36 range/oven requires 150 cfm minimum when located in an island configuration.

### **5.3.6. Identify Improper Storage of Volatile Organic Compounds and Household Chemicals**

Many household cleaning products, aerosols, pet supplies, insecticides, air fresheners, polishes, solvents, and adhesives contain potentially dangerous volatile organic compounds. If not stored properly, these chemicals can saturate the air in the living space and create significant health problems, especially for children and those with respiratory illnesses such as asthma and emphysema.

1. Inspect laundry centers rooms for the containment of laundry products. Most laundry products contain caustic materials such as chlorine and detergents that not only can burn the respiratory tract, but can corrode metals, including heat exchangers. Laundry products should be stored in airtight plastic containers and not in the typical cardboard boxes they are often purchased in.
2. Inspect under kitchen sinks for cleaning products such as scouring powder, powdered dish detergent, silver polishes and assorted cleaning solvents. If there is an odor of any of these products, then VOCs are escaping from the packaging and saturating the ambient air. All of these products should be packaged in airtight plastic containers and not in the cardboard containers they are often purchased in.
3. Inspect storage closets for improperly sealed containers of cleaning solvents, cleaning rags, and cloths used for polishing furniture, shining shoes, dusting, etc. Such cleaning fabrics should be stored in well-ventilated cabinets, outside of the living space.
4. Inspect for containment of paints, varnishes, furniture finishing products, solvents, stripping products, etc. Even though these products are usually stored in metal containers, it is often the case that the lids are not fitted securely to the container. Volatile organic compounds can easily evaporate out through even the smallest of openings, such as a paint lid that is not tightly fitted.

### **5.3.7. Determine Response Options to Any Identified Fuel Leaks**

All fuel lines and supplies should be inspected with combustible fuel detectors and identified leaks should be immediately corrected. Fuel leaks have the potential of contaminating the building, as is the case with kerosene or fuel oil. In the case of pressurized gas or propane, leaks can create life threatening fire or explosion potential. Minor leaks may require the simple tightening of a fitting or the replacement of a valve, but major leaks may warrant the shut-off of the fuel from its source until the repair is made. If a major fuel leak is discovered, the fuel vendor should be notified immediately. They may decide to lock the fuel valve until repairs have been made and inspected. This will prevent someone from using fuel in an unsafe situation.

1. Inspect fuel storage systems that are located outside of the building. Visually inspect oil storage for signs of leaks, corroded seams, or crimps in fuel lines. With gas detector, sniff around propane tanks and gas meters

2. Follow fuel lines from the entry into the building to each appliance, being sure to check each union, fitting and valve with the combustible gas detector. Use an indicator (colored ribbon) to mark any identified leaks.
3. Operate each appliance that opens the fuel valve, and check with the detector for leaks on both sides of the primary fuel valves.

### **5.3.8. Evaluate Any Lead Associated with Building Materials that May Require Handling in the Course of Any Proposed Work**

Where painted surfaces will likely be disturbed in the course of home performance services, lead-safe work practices must be used in homes built prior to 1978. It is important for the safety of the workers and of the occupants that any dusts, chips, and particulates of paint be carefully handled and removed.

1. Paints in homes built prior to 1978 are to be assumed to contain lead unless they have been tested and verified to contain no lead.
2. Samples of paint from surfaces that will be handled or disturbed in the course of home performance services can be collected and forwarded to a laboratory for analysis. If the representative samples prove to contain no lead, then additional lead-safe practices are not required.
3. The EPA requires that the publication *Protect your Family from Lead in Your Home* be provided to each household. In addition, the contractor should acquire a signed receipt from the homeowner attesting to the fact that the EPA literature has been distributed.

### **5.3.9. Inspect Building for Material Storage that Poses Potential Fire Hazard**

Most residential building fires could be avoided if combustible materials were properly managed and clearances around heat sources were properly maintained. The home performance inspection should identify potential fire situations and make fire safety recommendations.

1. No combustible material should be stored in the immediate vicinity of the heating system. The heating appliance should have a minimum of 2' clearance from combustible material for inspecting, accessing and servicing.
2. Water heaters should have no combustible materials in direct contact with the appliance and a clearance of 2' should be maintained around the burner area of the appliance.
3. Lint and dusts from clothes drying are highly flammable. Lint traps of clothes dryers are to be cleaned after each use and the area behind dryers should be kept free of dusts and lint deposits.
4. Ovens and ranges should be kept clean and free of debris, grease, and oils. Trash receptacles and combustible materials should be kept a safe distance from ovens and rangetops. Grease screens in range exhaust systems should be maintained in clean condition

5. Cleaning rags used for polishing, solvents, painting, etc. should be discarded after use. Saving such rags or storing them in confined areas can invite spontaneous combustion.
6. Verify the presence of smoke detectors on each level of the building and inspect each by activating the “test” button to assure they are working properly.

**5.3.10. Conduct Egress Evaluation and Provide Recommendations to Customer**

One of the least planned-for events in people’s lives is a residential fire. Even though homes are filled with combustion appliances and combustible material, a fire escape plan is something that very few think about. The home performance inspection is one of the few opportunities to provide an on-site egress plan for building occupants.

1. Inspect all entry doors to the living space to assure they are operational and have not been altered for added security or energy efficiency in such a way that they are difficult to operate. Consider the operation and height of locks if there are small children in the home.
2. Recommend fire drills to provide children with practice in exiting the building under duress.
3. Identify at least two potential exit paths from each room of the building.

## 6.0 Inspection and Diagnosis—Moisture

### 6.1. Scope

Moisture is one of the most destructive forces a building can face. It may affect the structural integrity of the building as well as health and comfort issues for the occupants. The source of moisture may be outside of the building or may be generated from within the building. Knowing the source(s) of moisture is key to controlling its impact. First you'll identify the source of the moisture, then you'll figure out the best way to control the moisture at its source.

### 6.2. Tools and Materials

Hygrometer, psychrometric chart.

### 6.3. Procedure

#### ***6.3.1. Conduct a Visual Inspection of the Building for Indications of Excess Moisture***

Many of the analytical tests for moisture are time sensitive, in that if the building inspection is conducted during a time of the year when the source of moisture problems are not manifesting, testing results will be less than conclusive. The visual inspection may identify indicators of excessive moisture that have occurred in the past, as well as those more current.

1. Access all areas of the building in your inspection. Moisture generated in one area can migrate to any other area by means of air leakage. For example, moisture from the crawlspace can traverse air by-passes in the building frame and manifest in the attic areas.
2. Inspect the exterior of the building and identify areas where grading, roof runoff, watershed from driveways and parking lot elevations directs water toward the building. Any of these scenarios can introduce an abundance of moisture to the building's foundation. Rainwater might provide 5–10" of water a year, but irrigation run-off could add another 200" a year. You can identify water problems by thinking about and observing how water moves through the land and the building.
3. Look at the land itself with respect to obvious running water, or water movement patterns. A "5% grade away from the building" is standard. Ridges and contours must be observed along with vegetational differences in the landscape. Drought-resistant vegetation should be considered as a water conservation measure.
4. Inspect the exterior of the building for signs of premature paint peeling, water staining, mold development and decayed building materials. Premature signs of material aging could be resulting from periodic (seasonal) exposure to moisture. In extreme situations, heavy fog can "moisture-load" a building over time. In the areas of any identified damage, check the moisture content of the building materials with a moisture meter. Moisture content should be below 15%.
5. Stucco buildings especially need to have proper drainage.

6. Stucco needs substantial drainage at the base of the exterior. Check around the base of the structure for the “weep-screed.” Weep-screed flashing allows moisture to exit the building while allowing air to enter. It’s common for the landscape to be covering the air movement required, so it’s important that the weep-screed always be open.
7. Check the condition of the sill-plate around the foundation.
8. If the building has accessible crawl space, go in and look for signs of mold growth, water staining, spalling of masonry materials. Check moisture content of any material that looks suspicious. Sample the moisture content of floor joists and sill beams for moisture levels over 15%. Examine around plumbing penetrations for typical moisture signs and inspect the integrity of moisture barriers in crawl space areas.
9. Water that wicks into the sub-floor can sometimes enter the house in the form of vapor. Serious vapor barriers can be effective against this, and are required in mountain climate zones.
10. It’s possible that excessive sprinkler activity— followed by excessive sun exposure— can drive moisture into wall systems.
11. From within the living space, inspect the window components for signs of moisture damage or mold development. As windows have a relatively low R-value, condensation often forms in this area before it develops in other areas.
12. From the interior, inspect the surfaces of exterior walls, especially in areas of high moisture production such as kitchens, bathrooms and laundry centers. If there is a mold odor, inspect closely in the back of closets, cabinets and behind base moldings. Moisture can be easily trapped behind wallpaper, especially vinyl wall covering, which restricts the drying action. Use a moisture meter to identify moisture content of surfaces that are in high moisture areas.
13. Access attic areas and inspect for moisture in areas associated with penetrations of the roof system, i.e., chimneys, vent pipes, valleys, and flashed attachments. Attics with kneewalls require close inspection. If no access is available, then an access should be made. Inspect the underside of the roof deck for water spotting or mold growth.
14. Inspect any penetrations between the living space and the attic, such as canned light fixtures, plumbing vent pipes or framing associated with kneewall construction. Look for any signs of moisture where heat might meet cold air.

### **6.3.2. Conduct a Relative Humidity Test**

Utilize a hygrometer in measuring the relative humidity of the various building zones.

A hygrometer measures the moisture that air is capable of holding at a given temperature. It is to be considered a relative test of current conditions, and may not really reflect the usual conditions of the building. For example, if the humidity test is conducted just after a dishwasher has been running, the results of testing might exaggerate the typical moisture level. If the house has been unoccupied for some time prior to the inspection, then it is likely that the relative humidity will be lower than if the building had been occupied. Testing of the relative humidity

makes it possible to identify a zone in the building that is more humid than other zones, and this could be a big clue in identifying the source of a moisture problem.

1. Activate the hygrometer within the living space and allow enough time for the temperature and humidity sensor to adjust to current conditions (it may take several minutes for a digital hygrometer to stabilize). If using a “sling” psychrometer, be sure to follow the manufacturer’s operating instructions. Record the humidity - and the corresponding air temperature.
2. Move to other zones of the building and repeat the test, recording the results for each zone. If the temperatures of various zones differ, then the relative humidity within those zones may differ, even if the grains of moisture within the air are identical. (Refer to the psychrometric chart for interpretation of testing results)

### **6.3.3. Utilize a Psychrometric Chart to Interpret Potential For Moisture Problems**

The importance of a psychrometric chart is that it provides an interpretation of when air of a certain moisture content will reach dew point (change from a vapor to a liquid). This is important to know for if dew point happens to be at a temperature frequently found within the building, then materials in this location will support mold growth, wood decay, metal deterioration, poor indoor air quality, etc.

1. Identify any areas of the building where cooler temperatures can be expected. These will include foundation walls, crawl spaces, window surfaces, attic areas and areas in the living space that do not benefit from space conditioning, i.e., closets, cabinets.
2. Measure the interior surface temperatures of materials in areas most likely to be cool in summer and winter. A spot radiometer works well for this task.
3. Determine the building “setpoints” for summer and winter space conditioning. This is most accurately determined by inquiring of thermostat settings from occupants.
4. Using a psychrometric chart, locate the conditioned room air for summer and winter conditions.
5. Identify the humidity level where the conditioned room air reaches dew point when lowered to the anticipated temperatures of the building surfaces.
6. Identify the relative humidity levels where room air will condense at the anticipated surface levels.
7. Propose corrections to eliminate potential condensation on the interior of building surfaces. This can be done in the following ways:
  - Maintain humidity levels well below the point where room air will begin to condense on cooler surfaces. This can be done with the use of a dehumidifier or efficient air conditioner during the warmest and wettest times of the year,
  - Insulate the surfaces where condensation is expected to develop. This might mean adding insulation to foundations and masonry surfaces and crawl spaces, window replacement or improvements of window U values.

- Improve convective cycling of heating systems to warm surfaces that are otherwise cool.
- Sealing any air leakage through the envelope that allows warm moist summer air to infiltrate into the building and that allows cold winter air to infiltrate and reduce the surface temperature of interior building materials.

#### **6.3.4. Evaluate the Causes of Any Mold and Mildew Growth in Closets, Corners, and Remote Areas of the Living Area**

Mold and mildew tends to develop first in closets, cabinets and corners where insulation levels may be minimized by framing material—or where cooler temperatures are experienced because of poor convective cycling. Where this situation exists:

1. Identify the insulation performance levels of the envelope to assure optimum temperature control in these confined areas.
2. Determine if the building frame has restricted insulation values in these areas. This is often the case in corners where several framing members, required for structural strength, limit the capability to effectively insulate the interior of the wall system.
3. Inspect for restricted air circulation in these areas. If space conditioning can not warm the surfaces, dew point will occur more often. Consider the replacement of solid doors to closets with louvered doors or removing doors.
4. Consider improving the insulation values of the area with rigid insulation installed on the interior of the wall studs. This technique may require the rigid insulation be covered with drywall for fire protection.
5. Consider ducting or directing supply or return air from the heating system to the areas where molds and mildews are found. This will serve to bring the area into the convective flow patterns of the distribution system.

#### **6.3.5. Evaluate the Impact of Humidifiers and Dehumidifiers Upon the Indoor Air Quality and Upon the Integrity of Heating/Cooling Appliances**

When the humidity levels within a building are outside of the recommended range of 30%–60% for extended lengths of time, humidifiers and dehumidifiers should be used to bring indoor humidity into the proper range. However, this can create a new set of indoor air quality problems, impacting on the performance of the heating and cooling appliances when such devices are installed directly in the distribution system.

1. Humidifiers and dehumidifiers often have standing water, which over time can be contaminated with molds and bacteria. When dirty appliances are operated, the health of occupants can be severely compromised. Where appliances are installed in the ductwork of heating or cooling systems, the ductwork can become contaminated with molds and bacteria. Routine cleaning of humidifiers and dehumidifiers is required.

2. Humidification control installed in ductwork is often located in the supply plenum, directly over the heat exchanger of the heating system. Moisture leaking onto the heat exchanger will eventually corrode the exchanger, causing it to leak flue gasses. This condition poses a serious health threat to building occupants and necessitates the replacement of the heating system.
3. Other less sophisticated humidification systems such as placement of pans of water on heating registers, venting the clothes dryer to the indoors or not operating ventilation fans when showering, should never be considered good humidification control strategies.
4. Use of humidifiers and dehumidifiers should be guided by information from accurate hygrometers. Many people operate equipment based on the season—or because of some health symptoms—with no real knowledge as to actual humidity levels.

### **6.3.6. Evaluate and Control Moisture Sources that Produce Condensation on Interior Building Surfaces**

Whenever moisture condenses on interior surfaces, the temperature of that surface has reached dew point. During cold weather, temperatures can cause windows and poorly insulated areas to develop condensation, even when the interior moisture levels are within the proper range. Remember that condensation can form during any season of the year. Likewise, water damage and mold development can occur during any season. To best control condensation on interior building surfaces:

1. Utilize a hygrometer in building zones to identify conditions where the interior relative humidity exceeds the recommended 30%–60%. Where such conditions exist, ventilate with dry fresh air if possible, or dehumidify if ventilation is not an effective option.
2. Maintain a thermal break and a capillary break between cooler masonry surfaces (foundation walls and slabs) and any porous building material (wood, drywall).
3. Seal air leakage between the interior and exterior. Moisture can be driven into the building envelope from both the interior and the exterior. Temperature differences created by air leakage can also bring an interior surface to the dewpoint temperature.
4. Exhaust excess moisture with point-source ventilation when moisture is being produced in the building. Cooking and showering are two of the more typical sources of excess moisture, but unvented combustion appliances, household plants, pets, aquariums and open sump systems are other potential sources.
5. Exhaust ventilators must be designed to effectively remove excess moisture from the building. Quality exhaust fans, dependable controllers, hard ducted vent pipes, terminations to the exterior of the building and proper maintenance are all requirements of an effective mechanical ventilation strategy.



## 7.0 Inspection and Diagnosis—Mechanical Ventilation Systems

### 7.1. Scope

The purpose of ventilation is to provide acceptable indoor air quality and an adequate oxygen supply. Identifying the effective ventilation rates of mechanical ventilators is important in assuring the efficient removal of point-source pollutants while maintaining recommended building air flow rates. Target ventilation rates must reflect the lifestyle of the occupants. The cfm ratings typically assigned to ventilators are a reflection of “best case performance,” and can be severely limited by such things as filter systems, venting design, duct materials, etc. Analytical testing is the recommended way to quantify appliance performance.

### 7.2. Tools and Materials

Digital manometer, Exhaust Fan Flow Meter™.

### 7.3. Procedure

#### **7.3.1. Identify Any Pollutant Sources Requiring Ventilation as a Control Method**

The investigation into household pollutants requires considerable background information about possible sources and the physical properties of several household pollutants. This, combined with good investigative technique may help identify situation where ventilation is the best means of pollutant control.

1. Interior moisture production from kitchen and bathroom sources should be ventilated from the building with the exhaust located as close to the source of moisture as possible. Look for visual indications of high moisture levels; peeling paint, mold growth, musty or heavy odors. Kitchen and bathroom zones should always have some form of mechanical ventilation.
  2. Foundation related moisture is best controlled by redirecting the source water whenever possible. When ventilation is used to remedy a damp cellar or crawl space area, it is important to introduce only *dry* make-up air. Otherwise, the ventilation system may be introducing more moisture than it is removing. Identify foundation moisture by visual inspection for molds, water spotting, spalling. Moisture meters are effective in determining the amount of moisture in building materials, including masonry.
  3. Clothes dryers should always be ventilated to the outdoors. Look for dust and lint deposits behind the dryer to identify leaks in existing ventilation systems, and look for associated moisture damage in the vicinity of the appliance. Dryer discharge usually has a distinctive odor of laundry soap and conditioners. NOTE: *The exhaust from clothes drying should never be allowed to discharge into the house; no heat or humidity reclaimer should ever be installed in the venting system.*
- Carbon monoxide from unvented appliances such as a ranges and ovens, is best deterred at the source through proper cleaning and tuning. If CO outputs from an appliance persist even after servicing, consider ventilation as a practical way to deal

with CO levels in the kitchen area. *CO levels at the flue of an appliance (or 12" above a range burner) should be lower than 100 ppm.* The range hood, if properly designed, can be effective at controlling reasonable and intermittent levels (under 10 ppm ambient).

However NOTE: mechanical ventilation is not a dependable strategy on which to justify the use of unvented combustion appliances. Testing of the ambient environment around each appliance, in accordance with the CO inspection protocol, will identify existing ambient levels. This does not identify CO production that may occur at a later date, if the appliance becomes dirty or out of adjustment.

- Radon is a potentially dangerous soil gas that moves into the building from the soil under and around the foundation. Exhaust ventilation from within the building would not be a good strategy as the negative pressures induced may draw more radon into the building. Sub-slab depressurization is a ventilation strategy that draws air from around the exterior of the foundation and exhausts it in a safe location. Where radon has been identified, this method of removal is the most successful. To identify radon levels within a building, placement of short term and long term monitors should be used. Laboratory analysis of monitors is provided after a one to three week exposure in the building. The Environmental Protection Agency has geographical maps of radon prone areas of the United States. Viewing these maps may give some idea of the probability of a radon problem, but radon is not predictable and periodic testing is recommended.
- Volatile organic compounds are usually brought into the house as chemical cleaners, solvents, insecticides, herbicides, etc., and stored in cabinets within the living space and in attached garages. It is best to store such products in an area outside of the living space. If they are stored in an attached zone, ventilation could be used to maintain the negative pressure necessary to keep the pollutants out of the living space. Identify volatile organic compounds by the associated odors, and by the storage practices of building occupants.
- Ventilation is not an effective means of controlling lead, asbestos, or combustible gas leaks.

### **7.3.2. Measure Capacity of Mechanical Ventilation Systems.**

Mechanical ventilators seldom move the amount of air required by the appliance rating. This is due to restrictions created by grills, venting materials, dirty fans and air vanes, air dampers and building pressures. The amount of air actually being moved by a small ventilation system can be determined with a Exhaust Fan Flow Meter, a device that measures the pressure across a hole of specific size. This device fits easily over bathroom exhaust grills and some kitchen exhaust appliances, but does not easily adapt to ventilators in awkward locations or larger ventilators.

1. Activate exhaust fan with control switch.
2. Connect digital manometer to the Exhaust Fan Flow Meter to measure pressure inside flow meter with reference to the living zone.

3. Adjust the Exhaust Fan Flow Meter orifice to one of the three opening size positions. Each orifice size effectively measures a range of fan flow—the larger opening, the greater the flow.
4. Place the Exhaust Fan Flow Meter over the operating exhaust fan, being sure to form a good seal between the meter and the mounting surface of the fan.
5. Measure the pressure created within the Exhaust Fan Flow Meter as the fan operates.
6. Calculate the amount of flow by referencing a flow chart for the orifice size and meter pressure.
7. If the exhaust fan is located in a zone that can be closed off from the living space by a door (as in bathrooms), close the door and repeat the test. It is possible that the fan will move less air in the closed zone. As this is the configuration that bathroom exhaust fans are typically operated, this should be the recorded flow rate.
8. When measuring the fan capacity of an inline fan with exhaust grills in 2 or more locations, follow the procedure above at each exhaust grill and add the results.
9. Larger exhaust fans with capacities over 200 cfm may be measured by interpreting the impact the operating fan has on the house pressure. Accuracy should be within 10%.
10. Configure the house for blower door testing by closing all exterior doors to attached zones. Close windows and doors to attached zones as well.
  - o Close off any other interior zones such as bedrooms or bathrooms that can be isolated from the zone containing the exhaust fan being tested.
  - o Conduct a blower door test on the building and the zone containing the exhaust fan and record results of testing at 50 Pascal.
  - o Remove the blower door and close the door opening, or cover the fan opening to create an airtight doorway.
11. Maintain a manometer that is measuring the zone pressure with reference to the outdoors.
12. Operate the exhaust fan at highest speed and measure the pressure difference created in the building with reference to outdoors. Record this number.

Interpret fan flow by referencing “Air leakage at various house pressures” chart located in appendix A-13 of Residential Energy.

### **7.3.3. Determine Ventilation Requirements Based on Building Use, Size and Occupants**

Building ventilation standards are based on the requirement to maintain clean, pollutant and odor free air for the occupants. The amount of ventilation required to provide this will vary from house to house, depending on building size, number of occupants and occupant lifestyles. Natural building leakage infiltration is not a dependable ventilation strategy, although sometimes it is reasonably effective. Each home should have well designed mechanical ventilation capable of providing the following:

1. Each occupant of the building should be provided with a minimum of 15 cfm. In instances where a building is obviously designed for more people than currently occupying, consider a minimum ventilation rate based on two persons for the master bedroom and one person for each additional bedroom. If a three bedroom home is currently occupied by a single person, base the minimum ventilation flow on four potential occupants ( $4 \times 15 = 60$  cfm). This is a good guideline, but ventilation rates must be tailored to reflect the lifestyle of the occupants.
2. Each building should have mechanical ventilation capable of exchanging .35 air changes per hour (ACH). To calculate the cfm rate that provides .35 ACH:
  - o Measure the conditioned square footage of the building and multiply this by the height of the conditioned area. The results will equal the total volume of the conditioned area in cubic feet.
  - o Multiply the cubic feet of conditioned area by .35 ACH the results will equal the total hourly air exchange rate.
  - o Divide the total hourly air exchange rate by 60. The results will equal the cfm flow rate that mechanical ventilators should be capable of providing.
  - o Select the larger of the two above calculations to determine appropriate ventilation requirements for the building.

#### **7.3.4. Determine the Most Appropriate Type of Ventilation System**

There are several different types of ventilation systems to consider; each has advantages and disadvantages. When considering options for a specific ventilation need, the variables are the initial cost of equipment and installation, the energy costs associated with exhausting conditioned air, the maintenance associated with performance and the effectiveness of the system to remove pollutants and provide healthy indoor air.

- Exhaust-only ventilation is typically the exhaust fan that draws room air and exhausts it directly outdoors. These are the least expensive and the simplest to design and install. Exhaust-only ventilation systems are usually very effective at removing point source pollutants such as moisture and odors from kitchens and bathrooms. They can be use intermittently, when pollutant strengths warrant their use. Exhaust-only ventilation can be established with one fan that draws air from two or more zones of the building. This strategy could be used to provide general ventilation for a building (other than the point source control of pollutants). Care must be taken to provide outside make-up air to the building or areas of the building where exhaust is taken from. Otherwise, negative pressures will arise that will impede airflow and reduce ventilation performance.
- Consider fans designed for continuous operation, even if the fan will not be operated on a continuous basis. Fans equipped with split capacitor motor are more energy efficient and durable.
- Consider fans with low “sone” ratings. The sone rating is the measure of noise produced by the fan. The noisier the fan, the less it will be used.

### **7.3.5. Determine Controller Best Suited For Mechanical Ventilation**

Selecting the proper controller for a ventilation system is an important part of the system design. It is seldom the case where ventilation should be at the total control of the building occupants, who may not follow a ventilating schedule or be aware of the ventilating needs of the building.

1. If bathroom exhaust fans are used solely for point-source ventilation of bathroom odors and moisture, then the controller should operate the ventilator when the bathroom is in use and then for a period of ½ hour after the bathroom is vacated.
2. If bathroom exhaust fans are used as part of the building's central ventilation, then the controller should operate the ventilator on a schedule of no less than twice a day for a selected period of time, or for an extended period of time on a variable speed controller, i.e., a 90 cfm fan could be established to operate at 45 cfm for 20 minutes on the hour, 24 hours a day. Overriding of the controller for full fan operation could be provided by incorporating a motion sensor or light switch into the fan wiring.
3. Kitchen range hoods are usually manually controlled and occupants should be encouraged to operate exhaust fan each and every time gas ranges and ovens are in use or when high amounts of moisture are generated, regardless of fuel type.
4. Radon control fans should be operated continuously, 24 hours a day, 365 days a year. Remotely positioning the fan will curtail noise and an operating indicator (light) should be installed to indicate fan operation.

Humidistat type controllers are effective in zones where high humidity is an anticipated problem. To be effective, it is important to assure that replacement air is less humid than the air being exhausted. Otherwise the fan may run continuously without a reasonable decrease in humidity levels.

### **7.3.6. Determine Proper Placement of the Air Supply and Air Exhaust Components of a Ventilation System**

Effective ventilation relies on the proper placement of the supply air and exhaust air locations.

1. All exhaust air must be discharged to the outdoors of the building. Exhaust should never be discharged into an attic in hopes that the attic ventilation will remove pollutants discharged into that zone. Ventilation exhaust should not terminate in the area of a soffit vent in hopes that the vent will provide an escape route for the exhaust. This strategy will fail because of wind pressure, poor design and high moisture content of the exhausted air.
2. All supply air for the house should come from a clean, fresh, outdoor source. Supply air should never be located near a combustion appliance vent or in a location where it could pick up air contaminated with auto exhaust, high moisture or chemicals. For purposes of combustion, make-up air should be delivered at least a foot from the floor and a foot

from any wall. At least two make-up vents should be considered so that a dangerous situation is not created if one vent becomes obstructed.

3. Point- source ventilation exhaust grills should be located as close to the source of pollutants as possible. This will assure the pollutant is captured quickly before it has a chance to diffuse into the surrounding house air.
4. If make-up air is provided to balance a zone being exhausted, consider positioning the make-up air conveyance in a location where it does not impose drafts or discomfort upon the occupants. This can be done in two ways. Position make-up air close to the exhaust, as in the case of a range hood exhaust, where make-up air travels a short distance to the exhaust, minimizing drafts in the living space. In the case of central ventilation, locating the make-up air in a remote location where it can be tempered before entering the living space, such as in the return air side of the heating/cooling distribution system.

## **8.0 Inspection and Diagnosis—Carbon Monoxide**

### **8.1. Scope**

Vented combustion appliances often produce varying amounts of carbon monoxide and other flue gasses, depending on the equipment design and maintenance. It is the purpose of the vent system to remove all by-products of combustion from the building. You'll move through the different systems at play, and test them individually and cumulatively.

An ambient carbon monoxide test should be conducted before any other work is started to assure that it's safe for the inspection. Another ambient carbon monoxide test must be conducted immediately after the operation and testing of all the vented and unvented combustion appliances found in the building.

### **8.2. Tools and Materials**

Differential manometer, pad and pencil.

### **8.3. Procedure**

#### ***8.3.1. Establish that the House Is Safe***

1. An ambient carbon monoxide test should be conducted at the very beginning of the building inspection, to assure the environment is safe for the inspector. An inside ambient reading (without any obvious source of CO) of 10ppm or higher than the outside ambient reading indicates that there's a problem. Be prepared to quickly identify whether a building has a serious carbon monoxide problem before getting started with other inspection topics.
2. Zero the carbon monoxide detector out in a CO-free environment, to establish the outdoor or background levels of CO.
3. Enter the building with the CO sensor operating and move from zone to zone, being sure to give the sensor enough time to collect an accurate sample. Perform your initial ambient test in the middle of the building, at least 10' from the nearest combustion appliance. Be sure that the customer has not used an unvented appliance within the last half-hour. Also check the kitchen area, the combustion appliance zone, attached garages, bonus rooms and the main living area on each floor.
4. If no levels of CO are identified, proceed with the inspection.

#### ***8.3.2. Determine the Operational Range For Each Draft in Each Vented Combustion Appliance***

1. Identify all vents and inspect each to make sure each is operational and in good working order. Look for any holes or gaps, disconnected parts or inappropriate materials in both exhaust and supply vents.
2. Look for atmospheric-vented appliances that rely on the temperature difference between the appliance, the appliance zone and the outdoor vent.

3. A combustion appliance that demonstrates a relatively strong draft on a cold winter day will likely have a much weaker draft on a warm summer day. Draft standards have been established to assist the inspector you in determining the required vent pressure for the testing conditions, and to assist in forecasting how the appliance vent will perform during seasons or conditions other than those existing at the time of the inspection. It's important to record the outdoor air temperature at the time of the vent test, and to compare the tested vent pressure against the minimum pressure required for that temperature.
4. Vent systems are also to be tested under "worst case conditions" and it may require some time to establish a draft, especially if the vent system is cold. The time it takes to establish a draft should be measured and recorded. This is referred to as "spillage," and should last no longer than 60 seconds. If the vent pressure takes longer than 60 seconds to become established, the appliance fails the test and basic corrections must be made.

### **8.3.3. Configure the Combustion Appliance Zone Into "Worst Case"**

Configure the house for testing by closing all windows, exterior doors, garage doors, and access to any unconditioned areas. This is referred to as "winter worst case" mode." Rooms with exhaust appliances should be open to the main living area, as is often the case with bathrooms, laundry rooms and rooms containing vented space heaters, or fireplaces.

1. Close all doors to rooms that contain only supply registers for forced air heating/cooling – this is often the case with bedrooms).
2. Close all window and exterior doors of the combustion appliance zone and close any doors between the zone and the primary living space.
3. Close all fireplace dampers and any other controllable dampers should be in the closed position. Overhead doors of garages and doors to zones outside of the living space should be closed.
4. Establish the benchmark pressure of the static combustion appliance zone with a differential manometer, measuring the combustion zone with reference to outdoors. This will be the base pressure of the combustion zone and will serve as a benchmark for testing. Record results.
5. Activate the exhaust fans and venting appliances found outside of the combustion appliance zone. These are usually bathroom exhaust fans, kitchen range hoods, clothes dryers, etc. Measure and record the pressure of the combustion appliance zone at this point and continue their operation for the remainder of the test.
6. Activate the exhaust appliances found within the combustion appliance zone. These are often clothes dryers, vented water heaters, and heating systems. Measure/record results and continue their operation for the remainder of the test.
7. Distribution systems for heating and air conditioning should be the last appliances activated for the test. Make sure that air filters incorporated in distribution systems are reasonably clean and do not obstruct airflow. Activate the distribution system and note

the change on the CAZ. If the active distribution system creates additional negative pressure to the zone, allow it to continue operating. If the active distribution system reduces the negative pressure within the zone, turn the distribution system off for the remainder of the test.

8. Worst case pressure of the combustion appliance zone has now been established. This is the maximum zone depressurization that combustion appliance vents will be expected to operate under. Consult identified standards to determine whether the zone passes or fails the zone pressure test. It is under this condition that carbon monoxide and vent pressure testing will be conducted.

#### **8.3.4. Determine If There Are Any Safety Issues With the Combustion Appliance Zone**

1. Always enter the combustion zone with caution. Carbon monoxide test equipment should be re-calibrated to outdoor ambient and operating before the combustion zone is entered. There are two issues to consider with regards to safety.
2. Those that could pose a threat to safety of the inspector during the testing of the zone, such as a blocked chimney vent.
3. Those with the potential to create damage at a future date, for example, high amounts of moisture caused by an unvented clothes dryer.
4. Use your senses, especially the sense of smell as you enter the zone. Pay particular attention to any odors of gas, mold and chemicals. Combustion gas testing for leaks should be conducted at gas meters, along gas lines and at appliances.
5. Inspect combustion appliances and appliance vent systems for proper clearances from combustible materials, and for signs of wear or damage.
6. Inspect for moisture excesses and mold growth. Water damaged building materials, rusted metal components and water staining.
7. Inspect for the safe storage of chemicals and consider options to storing chemicals and volatile organic compounds in areas outside of the building.
8. Inspect for indications of asbestos on hydronic systems, air distribution systems and combustion appliances. Be careful not to disturb any materials that appear suspicious.

Inspect the general condition of electrical wiring associated with appliances that will be tested. Do not operate appliances that contain frayed or scorched electrical wiring.

#### **8.3.5. Identify Any Issues that Might Require Immediate Attention**

Any issue that places the building or occupants in immediate danger requires immediate attention. Repairs need to be made as soon as possible. These are not limited to the following:

1. Fuel leaks—gas, propane and fuel oil leaks should be repaired as soon as possible. These leaks may already be at levels that pose fire or explosion hazards, or they may not yet be that significant. But fuel leaks don't repair themselves and left unrepaired, become more dangerous.

2. Flue gas spillage into the building—possibly caused by:
  - Improper pressures within the combustion appliance zone,
  - Deteriorating vent systems, or
  - Poor vent design.
3. High carbon monoxide levels in the combustion appliance zone. Levels in the zone of 10 ppm should be corrected immediately and carbon monoxide levels in appliance vent systems greater than 100 ppm should be corrected immediately. Unvented combustion appliances such as ovens and rangetops can produce carbon monoxide levels that elevate ambient levels to above the acceptable limit of 10 ppm.
4. High negative pressures in the combustion appliance zone. Testing may indicate that acceptable vent pressures are maintained in existing atmospheric appliances despite the presence of unacceptable levels of negative pressure in the combustion appliance zone. However, this fragile balance between zone pressure and vent pressure could be disrupted by external forces such as barometric pressure or wind pressure.

NOTE: Identified leaks in an older heat exchanger can seldom be repaired and will only become more pronounced with time

### **8.3.6. Identify the Proper Location to Conduct a Meaningful Carbon Monoxide Test**

There are a variety of combustion appliance and combustion vent designs, but in each case, the most accurate location for carbon monoxide testing is upstream from the heat exchanger, before the flue gas can mix with any room air or flue gas from another appliance.

1. Atmospheric gas appliances—CO sampling should take place directly over the heat exchanger and at least 6" before the flue gas mixes with dilution air from the zone. This test can be conducted by placing the CO probe directly into the exhaust port of the heat exchanger which can be accessed through the spillage opening on the front of the furnace cabinet. No hole need be drilled in the vent connect pipe. Where the dilution air or vent spillage is located somewhere in the vent connect pipe, flue gas sampling can be taken from a ¼"-hole drilled in the vent connect pipe, between the appliance and the dilution air opening.
2. Sealed combustion appliances—CO sampling should be conducted a few inches into the vent discharge pipe. In a sealed combustion system, the flue gas is not diluted with air from the zone, so the concentrations of CO at the vent discharge will be the same as at the heat exchanger. Do not drill holes in PVC pipe of condensing appliances if the vent discharge is accessible.
3. Power vented and fan assisted appliances—CO sampling should be taken upstream of the fan that powers the draft, (within 12") but before any other opening in the vent connect pipe.
4. Ovens—CO sampling should be taken from within the oven vent, usually located at the back of the range top. Run the oven for at least 5 minutes, making sure that the oven burner stays on. If there are two ovens—or two broilers—be sure to test each separately.

The CO sensing probe should be inserted into the vent so that gasses sampled are not diluted by additional room air at the vent opening.

5. Range top burners—CO sampling should be conducted at a level of about 6–12" directly over the flame. Obviously this location will allow for some dilution of combustion gasses from room air, but the mission here should be to identify burners that produce inordinate and measurable amounts of CO.

### **8.3.7. Follow Mechanical Operation of Combustion Appliances in the Proper Sequence**

When testing the vent pressures (draft) of combustion appliances, it is difficult to know beforehand, what constitutes “worst case,” but cold chimneys usually are part of that definition. Therefore, consider the following sequence—especially when two or more appliances are vented into the same vent system.

1. Start with the smallest appliance that has the longest vent connect run to the chimney. Smaller appliances (with a lower Btu rating) have the least ability to heat up the chimney.
2. Start up each appliance, one at a time. NOTE: If appliances are venting into a chimney that has already been heated by a larger appliance, “worst case” is not realized.
3. Larger appliances should be started up—one at a time—only after smaller appliances have been tested.
4. Collectively start up all appliances that are vented into the same chimney. This will help to determine if the chimney has the capacity to handle the flue gasses produced from the multiple appliances.
5. Check the pressure in the combustion appliance zone as the door between the zone and the living space is opened and closed. Select whichever position creates the greatest negative pressure in the combustion zone.

### **8.3.8. Test Drafts With the Use of Differential Manometer**

Appliance draft testing requires the use of a differential manometer capable of measuring 1 Pascal (.004 " of water column).

1. Drill a ¼"-hole in the vent connect pipe between the chimney and any existing dilution air opening in the vent pipe. If two or more appliance are serviced by the vent connect pipe, drill a ¼"-hole in each of the connect pipes between the vent connector and any openings serving as a barometric damper, dilution air, or spillage port.
2. Establish the manometer to check vent pressures with reference to the combustion appliance zone.

3. Note the draft at startup of the appliance and verify that draft is well established within the allotted 60 seconds. Allow the appliance to operate 4 to 5 minutes, measure draft and record results.
4. Where two or more appliances are connected to the same vent system, test each one and then test the draft of each appliance, with all appliances operating concurrently. The recorded results should be the lower draft pressure from the two tests.

### **8.3.9. Respond to Action Levels For Carbon Monoxide in the Home Environment**

Carbon monoxide production can usually be prevented in most equipment, with proper systems design and tuning. The exception is the cooking oven and range tops, which often produce carbon monoxide as a function of spreader plate design that causes flame impingement. Even brand new ovens can be problematic. NOTE: Be sure you've operated *all* appliances before doing interior ambient testing. If you haven't operated every appliance, you may be missing a big CO contributor.

Some suggested action level responses are included:

1. **100–400 ppm** measured in the vent system of VENTED combustion appliances or 12" above a range burner, gas oven or broiler. *Consider a clean and tune to correct fuel pressure, air to fuel mixture, dirty burners.* Up to 225 ppm CO is okay on a range.
2. **400 ppm** measured in the vent system of VENTED combustion appliances. *Clean/tune and if correction is not made, replace the appliance. Vendor lockout of the gas valve, until repairs are made and inspected, will prevent occupants from using appliance despite admonitions from inspector.*
3. **50 ppm** measured from ovens. The operation of any other unvented combustion appliance in the building should be strongly discouraged. *Provide clean/ tune, gas pressure check. If correction is not made, replace the appliance or provide point source ventilation i.e. range hood used during oven operation.*
4. **35 ppm** ambient level measured anywhere in the building, including combustion appliance zone. *Turn off contributing appliance, provide immediate ventilation of the house and determine if occupants are in need of any assistance.*
5. **10 ppm** ambient level measured anywhere in the building, including combustion appliance zone. *Consider clean/tune and repair of contributing appliances. Ventilation or replacement of ovens found to be the source of ambient levels.*

### **8.3.10. Inspect Ovens and Ranges For CO-Efficient Operation**

1. Inspect the burner orifices for cleanliness. Look for rust, scale and debris from cooking that may be interfering with the amount and pattern of gas at the burner.
2. If a spreader plate is part of the oven design, inspect for carbon buildup where the burner flames make contact with the plate. Warped spreader plates often produce high CO levels.

3. Observe the flame patterns from the lit burner. The flames should be well positioned on the burner, with no lifting, or erratic motion, which may indicate improper gas pressure. Gas pressures should be in the range of 3-½" of water column for natural gas and 10-½" of water column for propane. Pressure can often be checked at a pressure port on the burner manifold or at the gas valve. Wild and uncontrolled flames may also indicate an improper gas orifice is in use.
4. Inspect burner air tubes for debris or obstructions. Even cobwebs can change the air and gas mixing patterns.
5. Primary air shutters are sometimes adjustable. If the shutter is not properly set, poor fuel to air mixing occurs.
6. Inspect for flame impingement on metal surfaces. This is usually accompanied by soot or carbon deposits on the metal surface.
7. Look for signs of soot on vent caps terminating at the roof or exterior walls of the building.

### **8.3.11. Evaluate the Positions, Performance Features, and Operating Ranges of Existing Carbon Monoxide Detectors**

Carbon monoxide detectors must be installed in a manner that they sense the general ambient air. As with smoke detectors, ceiling installations should not be within 1' of a wall and wall installations within 1 foot of the ceiling, or in the corner of the room.

1. It is recommended that any home equipped with fossil fuel-fired equipment, or solid fuel-fired equipment (or attached garages) utilize carbon monoxide detectors on each floor of the building, being sure to have detectors located in the hallway outside of bedroom areas.
2. It is recommended that at least one hard-wired detector be installed in a building. It is prudent to install a detector that is primarily hard-wired but also has a battery back-up.
3. Carbon monoxide detectors for the home are built to the UL2038 standard for alarming, so they all respond or alarm at about the same levels of exposure. They are designed to alarm only after the detector experiences a particular level of CO for a given time.
4. Time-weighted response is a feature that prevents alarm activation under conditions that are not considered threatening. The impact of CO on humans is calculated in time-weighted concentrations.
  - **400 ppm** or greater—alarm within 15 minutes.
  - **200 ppm** or greater—alarm goes off within 30 minutes
  - **100 ppm** or greater—alarm goes off within 90 minutes
  - **30 ppm** or greater—alarm goes off within 30 days

### **8.3.12. Evaluate Any Potential for Occupant Exposure to Carbon Monoxide**

Carbon monoxide is a product of incomplete combustion, therefore any levels found within the building must originate at a combustion appliance.

1. Water Heaters—Atmospheric water heaters have a slight vent pressure, and are often positioned some distance away from the chimney. National studies have shown a high failure rate for water heater vent systems.
2. Gas ovens and range tops—Are notorious sources of CO in the ambient because they are unvented, are located directly in the living space and incorporate designs that invite CO production.
3. Attached garages—The cold startup of automobiles, lawnmowers, and gas power tools produce very high amounts of CO that can be drawn into the living area. Bonus rooms above garages may be especially receptive to air pollutants originating in the garage.
4. Furnaces and boilers—Venting systems and chimneys are often improperly maintained and obstructed. Heat exchangers do wear out and if laundry centers are in the combustion zone, the chlorine from laundry products can quickly deteriorate a heat exchanger.
5. Gas clothes dryers—Venting of clothes dryers is seldom taken seriously. The cheapest, poorest quality venting materials are often used and many people try to capture waste heat and moisture from clothes dryers. Yes, even gas clothes dryers.
6. Tobacco use in the home—Smoking in homes, especially those built to high energy performance standards can elevate the CO levels to above the action level for ambient.
7. Local industry, power generation and traffic—Outdoor levels of carbon monoxide can become elevated when there are large contributing sources and when weather conditions hold pollution close to the ground. Urban smog is a good example of pollution and weather combining to produce an unhealthy environment where CO is likely a factor.

### **8.3.13. Conduct a Carbon Monoxide Test of Gas Ovens and Range Tops**

1. Before testing ovens and ranges, first “zero out” the CO sensor in a CO free environment—outdoors if necessary.
2. Enter the zone where the oven is located with CO sensor operating and watch ambient levels carefully to assure the zone remains safe for testing.
3. Inspect the oven burner areas for signs of black soot and carbon development.
4. Check the oven and broiler areas (and remove any dishes, pot, foil liners and foreign objects) before turning on the appliance.
5. Turn the oven on to a high temperature setting to assure a sustained burner on time and locate (by temperature) the exact location of the oven vent.
6. Check and re-check the ambient levels in the area of 6' from the appliance for the first minute or two. Do not place the CO sensor probe directly into the oven vent at this

point. Some ovens start up by producing a large amount of CO that can saturate the CO sensor, which then requires several minutes to stabilize.

7. Once the oven has been operating for five minutes, check the CO levels of the flue gas. Place the sensing probe into the oven vent a few inches to avoid measuring flue gasses that have been diluted by room air. If CO outputs exceed 100 ppm, a cleaning and tuning is recommended. After cleaning and tuning by a qualified technician, oven CO outputs of 225 ppm are acceptable, providing this does not raise ambient levels above the 10 ppm level. If outputs exceed 50 ppm, a cleaning and tuning is required.

After ten minutes, check the CO levels of the ambient environment. This measurement can be taken within 4 to 10 feet of the appliance. Ambient levels exceeding 9 ppm should be corrected by cleaning and tuning, or by installing a point source ventilation system.

#### **8.3.14. Conduct Another Ambient Environment Carbon Monoxide Test**

Another ambient carbon monoxide test must be conducted immediately after completing the operation and testing of all the vented and unvented combustion appliances found in the building.

Some suggested action levels are included:

1. A second inside ambient read with the heating appliance(s) operating 10ppm or higher than the initial inside ambient, or,
2. A third inside ambient read at the closest supply register of a forced air furnace, or in the area of a non-forced air heating appliance that is higher than the second ambient reading taken with the heating appliance on.
3. Share results with the building's occupants. There should be results from three or more separate ambient tests:
  - o The combustion appliance zones, when vented appliances were being operated,
  - o The kitchen area when the oven/rangetop was operated
  - o The final walkthrough after all appliance have been operated.

The ambient level to record is the one with the highest tested parts per million.

**Table 8.1. Recording of test results**

	<b>Parts Per Million (ppm)</b>	<b>Inspector's Comments</b>
Heating:		
DHW:		
Oven:		
Pre-Living Space:		
Post-Living Space		

**Table 8.2. Drafting tests**

	<b>Yes or No</b>	<b>Outdoor Air Temperature</b>	<b>Draft</b>	<b>Inspector's Comments</b>
Heating Appliances				
Hot Water Appliances				
Other Flue Gases				
<b>Combustion Efficiency</b>				
Heating Combustion Efficiency	%			
CO2 or O2				
Smoke (oil)				
Temperature				
CO				

Notes:

## 9.0 Inspection and Diagnosis—Combustion Appliance Zones

### 9.1. Scope

Before performing an inspection for CO or a combustion efficiency test, it's important to clearly identify all the combustion appliance zones that should be included. Evaluation of a building's CAZs can be complicated because of the number of variables, and because all systems in a building are interrelated. A forced air distribution/heating system can have an unpredictable impact on the house – creating a negative or positive pressure in any combustion appliance zone. The primary questions that need to be answered are:

- How many combustion appliances exist?
- Where are the mechanical exhaust appliances located?
- How much volume of air does each exhaust fan actually move?
- When and where are doors typically open or closed?
- What are typical distribution system air movement patterns?

When you take all the combustion appliances, all exhaust fans and any return venting into consideration, the number of interactive systems can be quite high—but each must be considered in relation to the others.

### 9.2. Tools and Materials

Differential manometer, pad and pencil.

### 9.3. Procedure

#### 9.3.1. *Take Control of All Mechanical and Combustion Equipment*

Taking control of the combustion equipment means that you'll need to switch off—or switch to “manual”—any thermostats or humidistats that are in “automatic” mode. You need all combustion equipment to be on “manual.”

1. It is important to have a clear sense of the whole building with regards to air pressure and air movement. You'll need to carefully evaluate the impact that each combustion appliance zone has on every other zone.
2. Once an appliance starts sending exhaust up the vent pipe, that zone will create some level of negative pressure. The strength of the exhaust fan and the volume of the zone are the determining factors in how much it will impact on the CAZs in the building.

#### 9.3.2. *Configure the Building and Each Combustion Appliance Zone (CAZ) For Greatest Potential For Negative Pressure Within that Zone*

In fact, any zone in the building with a combustion appliance must be considered a combustion appliance zone. If there is a woodstove in the sunroom, then that room becomes a combustion appliance zone.

So for example, a fireplace in the living room makes the living room a combustion appliance zone. If the living room can't be closed off from the rest of the house, then the entire area becomes a combustion appliance zone, and your testing must reflect this situation.

What you are trying to do is to create a situation where the greatest negative pressure is in the main body of the house.

1. Configure the house for testing by closing all windows, exterior doors, garage doors, and access to any unconditioned areas. This is referred to as "worst case" mode. Rooms with exhaust appliances should be open to the main living area, as is often the case with bathrooms, laundry rooms and rooms containing vented space heaters, or fireplaces.
  - Close all doors to rooms that contain only supply registers for forced air heating/cooling—this is often the case with bedrooms).
  - Close all window and exterior doors of the combustion appliance zone and close any doors between the zone and the primary living space.
  - Close all fireplace dampers and any other controllable dampers should be in the closed position. Overhead doors of garages and doors to zones outside of the living space should be closed.
  - Establish the benchmark pressure of the static combustion appliance zone with a differential manometer, measuring the combustion zone with reference to outdoors. This will be the base pressure of the combustion zone and will serve as a benchmark for testing. Record results.
  - Activate the exhaust fans and venting appliances found outside of the combustion appliance zone. These are usually bathroom exhaust fans, kitchen range hoods, clothes dryers, etc. Measure and record the pressure of the combustion appliance zone at this point and continue their operation for the remainder of the test.
  - Distribution systems for heating and air conditioning should be the last appliances activated for the test. Make sure that air filters incorporated in distribution systems are reasonably clean and do not obstruct airflow.
  - Activate the distribution system and note any impact on the CAZ. If the active distribution system creates additional negative pressure to the zone, allow it to continue operating. If the active distribution system reduces the negative pressure within the zone, turn the distribution system off for the remainder of the test. Close off any venting that creates positive pressure on the appliance zone, for example, a supply-only ventilation system.
2. Worst-case pressure of the combustion appliance zone has now been established. This is the maximum zone depressurization that combustion appliance vents will be expected to operate under. The zone pressure minus the original benchmark pressure is the resulting "worst case CAZ pressure. Consult identified standards to determine whether the zone passes or fails the zone pressure test. It is under this condition that carbon monoxide and vent pressure testing will be conducted.

### **9.3.3. Perform Appliance Operations Testing**

For an effective test, all the forces that assert negative pressure on the building must be in play. The ONLY way to determine how these rooms will interact is to set up the worst-case scenario and see what happens.

1. Turn on each combustion appliance individually, and note the impact that occurs with regards to pressure changes.
2. Activate the exhaust appliances found *within* the combustion appliance zone. These often clothes dryers, vented water heaters, and heating systems. Measure/record results and continue their operation for the remainder of the test.
3. Activate the exhaust fans and venting appliances *outside* of the combustion appliance zone. These are usually bathroom exhaust fans, kitchen range hoods, clothes dryers, etc. Measure and record the pressure of the combustion appliance zone at this point and continue their operation for the remainder of the test.
4. If all exhaust fans are all upstairs and the CAZ is downstairs, you'll want to run all the exhaust systems at the same time and then see the impact that has on each CAZ. In most cases, the CAZ will experience the most negative pressure with the door to the living space close. But if large exhausting appliances are located in the living space, it is possible that introducing this space to the CAZ—by way of opening the door between—will create the greatest negative pressure upon the CAZ. The CAZ test must be performed with the door between the living space and the zone opened and closed. The “worst case” testing configuration is with this door positioned to create the greatest negative pressure within the CAZ.

### **9.3.4. Measure the Extent of Negative Pressure Created Within the Zone, Under Worst-Case Scenario**

The total volume of the air must be weighed against the total exhaust of the building (cumulative and individual)—and also the tightness of the building.

1. If there is a forced air distribution/heating system AND a water heater, it may be that the worst case might be with the furnace off, because when the furnace is on, the distribution system leaks could create a positive pressure in the combustion zone.
2. In southern states, where the outside air tends to be quite humid, building practices often result in positive ventilation that will have the impact of a forcing (dryer) indoor air out *through* the envelope. In humid climates, we don't want humid air drawn into the envelope because it will deposit moisture somewhere within the envelope.
3. Evaluate whether more negative pressure occurs with the zone closed off to the rest of the house, or whether there's more negative pressure with the door to the rest of the house open.

4. Identify the equipment or conditions that create that greatest negative pressure influence on the CAZ.

### **9.3.5. *Identify the Dynamics that Influence the Combustion Appliance Zone***

Make a flowchart or pressure map of the house to interpret and depict the results of your testing. This will be helpful in determining what repairs need to be made to correct pressures that exceed acceptable standards.

1. Any significant venting will have some impact on the CAZ, and this is what you need to chart throughout. Use arrows to illustrate how cumulative air movement impacts the CAZs.
2. Document each situation based on the number of CAZs and the number of venting devices, to make a flow chart of each situation with regards to pressure in each CAZ. If the pressure meter is more negative than the benchmark, then you know that there could be an issue to resolve.

## 10.0 Inspection and Diagnosis—Heat Exchangers

### 10.1. Scope

Heat exchangers can be subject to extreme conditions that over time can cause them to crack or deteriorate. If the integrity of the heat exchanger is compromised, flue gases can leak from the combustion side into the conditioned air (house air house (via the air side of the exchanger). This will cause a severe health and safety threat for the occupants, as the by-products of combustion are fatally poisonous.

The causes of heat exchanger deterioration are age and fatigue of the metal, as well as harsh environments that corrode the metal. Damage from high combustion temperatures, lack of proper air flow, or flame impingement upon the metal surfaces can also be problematic. The visual inspection of heat exchangers is difficult because the exchanger is encased in the furnace cabinet, with only portions of it accessible for visual inspection. Diagnosis involves a visual inspection as well as other chemical and pressure tests, depending on the type and construction of the heat exchanger.

### 10.2. Tools and Materials

Telescopic mirror or fiber-optic inspection scope, pressure-testing equipment, smoke-testing equipment, combustible gas analyzer, CO sensor, fragrant oil.

### 10.3. Procedure

#### 10.3.1. *Identify Design Specifications For a Variety of Heat Exchangers*

Heat exchangers are manufactured in various designs and using different materials. Newer, more energy efficient models are now being made using lighter alloys that allow for faster exchange of heat. Older systems tend to be more durable, but less energy efficient. The design of the combustion chamber and the heat exchanger will ultimately determine which tests are best suited for identifying leaks in the heat exchanger.



1. The “clamshell” type exchanger is typically used with atmospheric gas appliances that have more than one burner. Each burner tube has a dedicated pass-through in the heat exchanger, and a dedicated port that you can see from within the breach of the furnace. With this furnace design, you’ll want to visually inspect the flame for interaction with the distribution fan, which would indicate air moving across the heat exchanger.
2. The “drum” type heat exchanger is typically used with power gas and oil-fired furnaces. The drum is double-walled. Combustion gases pass between the walls of the drum

while the air from the conditioned space house air moves around the outside. As the combustion chamber is usually more enclosed, flame inspection is often difficult, so your inspection should include pressure-testing.



3. The “boiler” type heat exchanger is characterized by boiler tubes or boiler plates. Both designs are full of water, so you’ll want to do a visual inspection for water leaks. There may also be rusting associated with condensation. Find out if the occupant is continually adding water to “top off” the water levels in the system
4. Newer gas appliances in the 78% and 80% AFUE range most often use a serpentine heat exchanger to increase the heat exchange from combustion gases. A serpentine is essentially a tube heat exchanger that makes approximately four passes back and forth so the combustion gases can give up more heat. Given the nature of a tube that makes several 180° turns, a visual examination from the inlet or outlet of the tube will reveal little if a problem is suspected. Burners used with serpentine heat exchangers are of an inshot design. This style burner does not exhibit a wavering flame as the old style burners did when the integrity of a heat exchanger was corrupted. Serpentine heat exchangers should be visually inspected when possible by removing the blower assembly, and when feasible, from the plenum area. Pressure and O<sub>2</sub>/CO<sub>2</sub> testing is required to complete the heat exchanger inspection. Under conditions where a large crack has occurred, the draft proving switch will likely open creating an intermittent heat complaint from the client.
5. Gas appliances in the 90%+ AFUE range have a serpentine heat exchanger as described above. In addition, there is a secondary condensing heat exchanger located between the primary serpentine and the blower assembly. This secondary heat exchanger is made of a non-corrosive material and is of a plate or finned tube design. The design and placement of the secondary heat exchanger make it difficult to impossible to perform a visual inspection of the primary serpentine heat exchanger. The technician must rely on a pressure and O<sub>2</sub>/CO<sub>2</sub> testing for heat exchanger inspection. The secondary heat exchanger is meant to handle condensate. Inspection typically relies on checking for leaking condensate.

### **10.3.2.      *Inspect For Indications of Heat Exchanger Deterioration***

The visual inspection for heat exchanger deterioration can be quite challenging as the exchanger is generally well enclosed within the furnace cabinet and has many small passages to help in the rapid transfer of heat. However, with the right tools and some inspection techniques, the visual inspection can provide a nearly complete evaluation. Look for areas of rust, corrosion, fine hairline or larger cracks.

1. Identify any burn marks or scorching on the outside of the cabinet. This may indicate a particularly hot area where flue gases are being directed toward the cabinet, rather than toward the breech of the furnace.
2. Access the combustion chamber with a small telescopic mirror that allows you to see into relatively remote areas. A fiber-optic inspection scope also works well, and has the advantage of a built-in light source. You'll want to examine as much of the heat exchanger as possible from within the combustion chamber, being sure to check areas where flame impingement can occur - and in the corners where condensation is likely to occur. Examine the bottom of the combustion chamber and the top of the burner heads for any buildup of rust and scale. This is an indication that deterioration is occurring.
3. Access the supply plenum with a mirror or fiber-optic scope, and check the upper portion of the heat exchanger in the same manner. Inspect the inside of the supply plenum for signs of soot, smoke or deposits from combustion. While accessing the supply plenum, place a bright light or drop cord into the combustion chamber, and inspect for light that may be seen from the supply plenum.
4. Operate the appliance. Atmospheric gas appliances require that you pay particular attention to the pattern of the flames on the burner tubes. The burner will fire for a minute or two before the distribution fan starts up. As the distribution fan begins to operate, watch the flames for any change in the pattern (or direction) of the flame tip. Air from the distribution cycle blowing across the burner is a strong indicator of a leak in the heat exchanger.
5. Examine the supply registers and the walls, including the carpeting and drapery around the registers. If a dangerous long-term leak has been providing combustion products to the house air, visual indicators may exist.
6. If a cold weather inspection is being conducted, you may find a leaking heat exchanger that is providing moisture to the house air and causing condensation to form on the windows. Ask the occupants about any condensation problems during times of furnace operation.
7. Ask the occupants about any seasonal respiratory illnesses or any odors of combustion that may exist. Ask about any alarm activity from carbon monoxide detectors.
8. Identify any environmental factors that may create harsh conditions for the heat exchanger. This could include the furnace being located in a high moisture area, or in a zone also used for laundry. The chlorine used in laundry products is extremely corrosive to heat exchangers, especially those of high efficiency furnaces.

### **10.3.3. Perform Appropriate Tests According to the Type of Heat Exchanger**

Several tests exist to evaluate the integrity of heat exchangers. Some of them are more applicable to sealed combustion systems, while others are more effective for atmospheric draft appliances.

1. Tracer gas tests are effective for most heat exchangers. The test consists of sealing the breach of the furnace (exhaust port) and flooding the combustion chamber with a mixture of methane and an inert gas - and then testing within the supply plenum for traces of the methane with a combustible gas detector. Do not attempt this yourself without supervision unless you have done this before.
2. Pressure-testing of the heat exchanger works well for appliances with a sealed combustion chamber, such as a high efficiency sealed systems or and oil furnaces. A differential manometer is established to measure the combustion chamber with reference to the outdoors. The primary and secondary air sources to the chamber are sealed with duct tape, as is the exhaust breach of the furnace. You'll note the pressure of the combustion chamber with reference to outdoors. With a blower door, you can depressurize the house and the ductwork to identify any changes in the pressure of the combustion chamber. NOTE: This test does not work well with atmospheric gas appliances, as it is difficult to positively seal the secondary air supply.
3. Smoke-testing requires placing a smoke bomb (available at heating supply centers) into the combustion chamber and then identifying any smoke passing into the supply plenum. The breach of the furnace should be sealed for this test—so the concentration of smoke remains in the combustion chamber.
4. Use a CO sensor to monitor carbon monoxide readings at the supply registers. This is an indication that the heat exchanger is leaking, but this test is only appropriate when carbon monoxide is a product of the combustion process. If carbon monoxide is NOT a product of the combustion, then a negative reading at the supply register should not be taken as verification of heat exchanger integrity.
5. Draft testing provides a simple means of testing heat exchanger integrity. Measure draft when the burner fires into a warm chimney, and monitor the draft as the indoor blower starts up. This will occur within several minutes of burner ignition. If the draft decreases to 0"WC—or goes positive—the integrity of the heat exchanger is suspect as the high pressure from the blower motor will more than overcome draft from the chimney. Although the draft proving switch in 78% AFUE and above furnaces will shut the burner down on safety in this situation, a small crack may show up as a slight decrease in negative pressure.
6. Use a combustion analyzer to perform a chemical analysis of the flue gas. If this device continuously reads carbon dioxide or oxygen, there may be a crack in the heat exchanger. A crack could be the cause if while the burner is on, the percentage of oxygen/carbon dioxide changes when the distribution fan starts up. This indicates that the distribution fan is introducing oxygen to the flue gas and raising the oxygen content (or lowering the carbon dioxide levels). However, even if flue gas properties *don't* change when the distribution fan goes on, this is NOT proof positive that no crack exists. It is possible for a crack to be located in an area where oxygen is not forced into the combustion process, and pressure within the combustion process prevents the crossover of oxygen.

7. Use an oil with a strong fragrance (for example, oil of wintergreen) to test for leaks in the combustion chamber. Insert the oil into the combustion chamber (NOT during firing cycle) with a small syringe. If odors pass through the heat exchanger, they will likely be identified at the supply registers. Note that if any oil is spilled accidentally, the odor could be drawn into leaks on the return side distribution and void the test. This test can also be used on sealed combustion as well as powered gas and oil systems. It is NOT recommended for atmospheric gas appliances.



# 11.0 Inspection and Diagnosis—Combustion Efficiency, Flue Capacity, HVAC, and DHW

## 11.1. Scope

This inspection involves comprehensive testing of HVAC equipment including the heating, air conditioning and domestic hot water. These tests should be conducted periodically as performance functions will likely change with use of these appliances. The health and safety of the occupants and the energy efficiency of the building is very dependent on the performance features of these appliances.

## 11.2. Tools and Materials

Flashlight with drop cord, mirrors, drill and ¼" drill bits, differential manometer or magnehelic, vent sizing tables, tape measure, combustion analyzer probe, pyrometer, thermocouple or stem thermometer, amp meter, combustible gas detector, a spray cleaner formulated for cleaning the copper and aluminum, cooling system fin comb, flow meter or duct blaster.

## 11.3. Procedure

### 11.3.1. *Identify Design and Performance Specifications For Combustion Appliances*

The manufacturer's rating plate and the owner's manual will provide installation and performance specifications for the appliance. It is important that you collect relevant information for determining proper performance, for providing energy analysis, and for recommending improvements related to the appliance.

1. Record the manufacturer, model number and serial number of the appliance for referencing performance characteristics (GAMA) and replacement parts, if needed.
2. Identify appliance input and output ratings of the appliance. This will determine the Annual Fuel Utilization Efficiency of the appliance (EF if it is a water heater or RE if it is a big water heater), and help in determining if appliance is provided with the proper volume of fuel and combustion air.
3. Identify the proper venting category of the appliance as per NFPA 54. (Category I appliances have negative pressure vents and vent temperatures above the condensing temperature of the flue gas. Design and specifications for category 1 appliances are contained in NFPA 54. Category IV appliances have a positive pressure vent and vent temperatures below the condensing temperature of the flue gas. The manufacturer's installation specifications serve as the vent installation and standards guide as per NFPA 54.
4. Identify the type of gas valve: single stage, multiple stage, variable rate.
5. Determine if appliance utilizes an ECM motor (Electronically Commutated Motor) for energy efficiency.

6. Identify the rated distribution fan capacity (fan curve) for comparison to actual fan flow. Refer to the information plate or the manufacturer's website service manual for fan curve information (many manufacturer's list the fan volume at .2" of water column on the manufacturer's plate).
7. Identify the recommended temperature rise across the heat exchanger. By comparing the recommended to actual temperature rise, evaluation of possible performance improvements can be made.

### **11.3.2. Configure the Building For Combustion Appliance Testing**

All combustion appliance tests—including appliance efficiency testing, carbon monoxide testing and vent pressure (draft) testing—should be conducted with the building and the combustion appliance zone configured into “worst case,” meaning that all possible negative pressures that can be exerted upon the combustion appliance zones, have been provided.

1. The building should be closed up, as in the winter mode, with all primary doors and windows closed.
2. All exterior doors and windows of attached zones, i.e., garages, sunrooms, etc. should be closed, as in the winter mode.
3. Attached zones like enclosed porches, garages, etc. should be closed from the main living area unless they contain exhaust appliances capable of creating a significant level of negative pressure in the zone in which they are located.
4. Close any passive ventilators that can be manually closed, such as fireplace dampers.
5. Operate any exhaust only appliances, such as bathroom ventilators, oven/range exhaust ventilators and clothes dryers.
6. Determine interior door configuration that creates the greatest negative pressure upon the combustion appliance zone. Generally, interior doors should be open, but doors between the CAZ and the living space must be tested both opened and closed, to determine “worst case” depressurization of the appliance zone.
7. Close fireplace dampers and fully open all supply registers.

### **11.3.3. Determine the Appropriate Location to Collect Combustion Gas Samples**

Measuring the characteristics of the combustion gas will indicate how efficiently the fuel is being combusted, and provide information about how to improve the fuel utilization efficiency. It is important that flue gas samples be collected from the proper location of the vent system—before any room or dilution air is mixed with the exhaust—as this would cause the gas sample to register a lower combustion temperature and a higher oxygen content and render the testing inaccurate.

1. Condensing furnaces and power-vented appliances (All Category III and IV appliances): Collect flue gas sample at the vent termination. Position the probe of the combustion analyzer a few inches into the vent before the sample is diluted with ambient air.

Category III and IV appliances have positive pressure vents, and those vents should never be compromised by drilling sampling holes.

2. Fan-assisted appliances (Category I): Collect flue gas sample through a ¼"- hole in the vent pipe, a few inches downstream from the fan that serves to draw air through the combustion chamber.
3. Atmospheric gas furnaces and space heaters: Collect flue gas sample directly in the heat exchanger accessed through the draft diverter, before the exhaust mixes with ambient air from the combustion zone. No hole in the vent connect pipe is required as the probe of the analyzer can be positioned 4–6" into the passage of the heat exchanger through the opening of the draft diverter. Each burner will have its own passageway through the heat exchanger and a gas sample must be taken from each heat exchanger passage.
4. Atmospheric boilers: Collect flue gas sample from a ¼"-hole drilled in the vent connect pipe between the boiler and the draft hood.
5. Oil appliances: Collect flue gas samples in the vent connect pipe after the breech and before the barometric damper.

#### **11.3.4. Determine When “Steady State” Has Been Attained by Temperature Readings**

When testing for combustion appliance efficiency, it is important that flue gas samples and performance features of the appliances be monitored at “steady state.” This refers to the point where the combustion appliances have reached equilibrium in the combustion process. Appliances require a “ramp-up” which is the warming up of the internal components and the vent system during which time they are not operating at peak performance. It is hoped that by properly sizing appliances to the required loads, that they will ultimately operate at steady state for most of their operating cycle, as this is where the greatest efficiency is achieved.

Steady state is determined when the stack temperature of the flue gases has reached the maximum temperature and no longer increases, as measured with a pyrometer or thermometer capable of measuring temperatures in excess of 1000°F.

1. Determine the proper place in the flue gas stream to measure the flue gas temperature.
  - Condensing furnaces or power-vented appliances: Measure stack temperature at the discharge of the vent. Do not drill holes in plastic vent pipes of high efficiency or Category III appliances.
  - Atmospheric gas furnaces and space heaters: Measure stack temperature directly over the heat exchanger, a few inches before the flue gas mixes with room air from the spillage or dilution air opening.
  - Atmospheric boilers: Measure stack temperature through a hole drilled in the vent connect pipe between the boiler and the draft hood.

### **11.3.5. Measure Samples of Combustion Products and Combustion Gas Characteristics**

A combustion analyzer is used to measure characteristics of the flue gas when the combustion appliance has reached “steady state.” Through the measurement of the flue gas temperature, carbon dioxide/oxygen levels, carbon monoxide levels and smoke levels (oil fired appliances), a determination can be made about the efficiency of an appliance that converts the potential Btus of the fuel into heat energy.

1. A draft test should precede combustion analyses to ensure products of combustion can exit the appliance being tested.
2. A thermocouple or pyrometer should first measure the stack temperature to determine when “steady state” operation has been reached. No flue gas sample should be taken prior to the system attaining steady state.
3. Oil and LP appliances should have a smoke test performed *before* starting combustion analysis. Any smoke staining indicates inadequate air for combustion, and should be corrected before time is spent on combustion analysis.
4. A combustion analyzer probe, after calibrating or zeroing the instrument, should be placed into the flue gas stream at the appropriate location, depending on the type of appliance being tested.
5. The probe should be placed in the center of the flue gas stream for the most accurate sampling.
  - o Carbon dioxide and oxygen are measured as a % of the flue gas.
  - o Carbon monoxide is measured as parts per million.
  - o Smoke is measured as a number that corresponds to the level of staining (white to gray to black)
6. For electronic analyzers, select the fuel type for the appliance tested and program the fuel type code into the analyzer. For the wet-kit (chemical fluid) type analyzer, the test results will be charted on a scale for a particular fuel type.
7. Electronic analyzers utilize an electronic pump to draw flue gases across the sensors. Allow enough time for the pump to completely purge the line of the analyzer. This will usually take 60 to 90 seconds. If the sampling properties are digitally displayed, allow them to stabilize before recording.

### **11.3.6. Maintain and Properly Utilize Combustion Efficiency Test Equipment**

Combustion efficiency test equipment should be considered a sensitive piece of equipment that may have many performance features and components—and can be an expensive tool to purchase. If improperly stored or operated, maintenance will become even a greater expense. This equipment should be used only in accordance with manufacturer’s operating specifications.

1. Technicians responsible for using the equipment should receive proper training and should have read the operator's manual. Many warnings appear in equipment manuals to help identify potentially harmful or unsafe operating conditions.
2. A copy of the operator's manual should accompany the equipment at all times—for field reference.
3. The manufacturer should routinely provide calibration of oxygen, carbon dioxide, carbon monoxide sensors, and thermocouples. The frequency of calibration is dependent on the amount of use the equipment receives, but should occur at least once a year.
4. Filters and condensate traps should be frequently cleaned.

### **11.3.7.      *Perform a Combustion Efficiency Test and Compare Results to Manufacturer's Specifications***

The combustion efficiency test involves the measurement of flue gas properties, the analysis of those properties, and the comparison of the results to the specifications by which the equipment is manufactured and rated. The appliance "steady state efficiency" is a function of the net stack temperature of the flue gases, and the percentage of carbon dioxide or oxygen found in the flue gas.

1. Sample the flue gas and measure the properties, as described above. Be sure to use the equipment in accordance with the manufacturer's operating procedures.
2. When using a wet-kit type analyzer, determine the steady state efficiency from the readout provided by test equipment - or by using the appropriate fuel chart.
3. Determine the manufacturer's AFUE rating (US Department of Energy's Annual Fuel Utilization Efficiency) for the appliance by dividing the appliance output by the appliance input. These numbers should appear on the appliance rating plate, or in the appliance product literature.
4. Compare the steady state efficiency to the manufacturer's AFUE that is listed on the appliance rating plate. The AFUE represents optimum burner efficiency (SSE), minus some anticipated heat losses that include standby losses up the vent pipe—and jacket losses radiating off a heated combustion appliances. The AFUE will be a slightly lower efficiency than the SSE, usually a 3 to 4% difference.
5. If the rated AFUE is the same or higher than the steady state efficiency, then the appliance would benefit from further inspection and servicing.
6. Before moving on, plug any holes drilled in vent connect pipes with ¼" stainless steel cap.

### **11.3.8.      *Measure the Temperature Rise Across the Heat Exchanger***

Measuring the temperature rise across the heat exchanger can provide important insights into performance features of a forced-air furnace. The difference between the supply and return air temperatures is referred to as the temperature rise. The manufacturer will specify the

temperature rise for the appliance on the manufacturer's rating plate, which is located within the appliance vestibule. Proper temperature rise (is usually in the 40 degree to 70 degree temperature difference). High efficiency appliances will have a lower temperature rise (40–50 degree range) than less efficient appliances. Oil appliances and conventional efficiency appliances (80 to 85%) typically have a higher temperature rise of 60–70°F. Proper temperature rise may be as low as 250°F for condensing gas appliances, to 2000°F for oil appliances—but will always occur within a range. High efficiency appliances will have a lower temperature rise range than less efficient appliances. Oil appliances typically have the highest temperature rise. If the temperature rise is too low then the air delivered to the house will be uncomfortably cool. If the temperature rise is too high, it will eventually damage the heat exchanger and detract from the energy efficiency of the appliance. This situation will usually cause the flue gas temperature to increase and the SSE to dramatically decrease.

1. Drill a small hole in the supply and the return plenum of the furnace and place a thermocouple or stem thermometer in each plenum. The test location on the supply air side should be in a location that is out of direct line of site from the heat exchanger. This will most likely place the test location in the main ductwork. Radiant heat from the heat exchanger will produce an inaccurate reading that may be as much as 200–300°F higher than actual air temp leaving the heat exchanger. For systems that utilize more than one trunk duct that originates from the plenum, be sure to test the air supply temperature from each main trunk and then average the temperature.
2. Operate the appliance to steady state, and measure the temperature in each plenum. The return plenum temperature will closely equal the air temperature of the living space. The supply air temperature will equal the temperature of the air as it leaves the heat exchanger.
3. Compare this temperature rise to manufacturer's recommendation. Temperatures exceeding the recommended could be caused by dirty heat exchanger, lack of or restricted return air volume, restricted supply air volume, dirty furnace filters, slow fan speed, dirty blower vanes or an over fired appliance. Temperatures too low can occur from high fan speeds and excessive size ducts.

### **11.3.9. Identify Techniques for Inspecting Combustion Chambers For a Variety of Appliances**

Inspection of the combustion chamber is conducted to identify problems that may exist with the burner assembly, with the containment chamber and with liners that may be incorporated in the chamber. Deterioration of the chamber may create potential fire hazards, carbon monoxide production and general inefficiency of the combustion process.

1. Identify any scorching of the appliance cabinet, as this may indicate a breach in the combustion containment.

2. Inspect for soot around doors, seams, and inspection ports of the combustion chamber. This may indicate a blocked heat exchanger and the possibility of a combustion chamber that operates under a positive pressure.
3. Visually inspect the heat exchanger, combustion chamber and burners for excessive hot spots, rust and scale deposits. Excessive deposits within the chamber could indicate metal deterioration.
4. Inspect the liner of oil-fired appliances for cracks, breakage, and deterioration.
5. Observe the flame of atmospheric gas appliances at the startup of combustion. Identify flames that roll out the front of the combustion chamber.
6. Observe the flame of an operating appliance. Gas flames should be steady, with no lifting off the burner, (In-shot style burners found on most 78% and higher AFUE appliances may not exhibit any fluctuation unless a large void is present in the heat exchanger). Identify any gas flame that comes into direct contact with the combustion chamber or the heat exchanger. Oil flames should not extend past the targeted liner of the combustion chamber and flame should not leap off the burner head. The end cone of an oil burner should not extend into the combustion chamber.
7. Use a manometer or magnehelic to measure draft as the blower starts up. Loss of draft at that point may indicate a cracked heat exchanger.
8. Appliances with serpentine heat exchangers and secondary heat exchangers will be difficult to inspect visually. Rely on instruments as well as your limited visual inspection on these appliances.

### **11.3.10. Evaluate Thermostat Performance**

The thermostat is a relatively simple device that controls the operation of the appliance. Boilers with zone controls may fire or simply activate circulation pumps. The thermostat will directly activate space heaters and air conditioners. It is important for comfort and efficiency that thermostat performance is accurate.

1. Analog or mercury switch thermostats must be mounted plumb and level for accuracy. There are usually reference guides on the surface of the mounting plate. Digital thermostats do not require leveling to operate properly, but should also be level for aesthetics.
2. Mercury switch thermostats must remain free of dust and debris to operate accurately. Pull the faceplate to inspect and clean.
3. Check the accuracy of the temperature readings by placing a thermometer of known accuracy in the vicinity of the thermostat and verify accuracy to within 2°F.
4. Check the anticipator setting of mechanical thermostats by measuring the electric current of the heating controls with an amp meter and positioning the anticipator setting to the measured amperes. The most accurate method of testing the anticipation current is to remove the thermostat from the sub-base, and then touching your in-line amp

meter probes to the “R” and “W” terminals on the sub-base. This will measure amp draw of the heating controls and any excessive resistance from the thermostat wire.

5. Appliances with AFUE rates of 78% and above may require a longer run time than setting the anticipator as explained previously may produce. Look on the manufacturers rating plate or in the installation instructions to determine the proper anticipation setting with these appliances.
6. Digital thermostats have no anticipation setting, but utilize cycle rate instead. Instructions for setting cycle rates are located in the instruction manual of the thermostat, or may be found on the back plate of the thermostat. Most appliances of 78% AFUE and higher require a cycle rate of 3 to 4 cycles per hour. A higher cycle rate may increase the likelihood of condensation occurring in the flue.
7. It is important to seal and wiring holes or openings behind the thermostat, if possible. This will prevent the thermostat from sensing temperatures inside the wall that do not accurately depict the room air temperature. The most important performance factor for a thermostat is caulking the wire hole behind the thermostat—if that’s possible.

#### **11.3.11. Evaluate Thermostat Location With Relationship to Occupant Comfort**

The location of the thermostat is important for proper control of the conditioned space temperature. The thermostat should be located in an area where it accurately senses and responds to the temperature of the living space. If this is not the case, occupants will not be comfortable and will make adjustments to the thermostat to compensate for their discomfort.

1. Thermostats should be located on an interior wall, at a height of approximately 4' off the floor. If a thermostat is located on an exterior wall, it will likely sense the radiant temperature of the wall, more than the actual room temperature. If located too low or high on the wall, it may sense the stratification of air, which is not what the occupant is sensing.
2. Thermostats should be kept away from appliances that generate heat, such as televisions, lighting fixtures, refrigerators, etc. These may provide a source of heat that satisfies the control, despite the room temperature.
3. Thermostats should be positioned away from heat supply registers or radiators that may give the control a sense of heat that doesn’t reflect the actual room air temperature.
4. Some resistance heaters are equipped with individual thermostats located directly on the heater. This is a poor design because resistance heaters are usually located along the floor on exterior walls. This usually means the thermostat is never really sensing the room air temperature.

### **11.3.12. Evaluate the Benefit of Installing a Setback Thermostat**

Programmable thermostats offer the ability to automatically control temperatures based on the time of day or night and day of the week. This provides energy efficiency by setting back the temperature when occupants are scheduled to be away from home or through the night when they are sleeping. The savings realized by using setback capabilities can be 5% to 10% of space conditioning costs.

1. Many households—especially those occupied by the elderly—are intimidated by digital programming. Do not install thermostats that are complicated or difficult for the visually impaired, or use math to program. Select a model with a large display for those installations where individuals may have visual problems.
2. Install thermostats with battery back-up or a model that remembers setting without a backup battery, so in the event of a power failure, the program is not lost.
3. Install setback thermostats where occupants agree to utilize at least a 5-degree setback at night, or when routinely away during the day.
4. Select a model that does not require a common wire to be run from transformer on the appliance—unless new wiring is being pulled in anyway.

### **11.3.13. Identify Fuels and Distribution Systems Used Within a Building**

Frequently, primary space conditioning systems are augmented with secondary or tertiary systems. It is important that each and all space conditioning systems be identified to determine the actual fuel used through the heating and cooling seasons, and also for predicting potential indoor air quality issues if unvented combustion appliances are used.

1. Ask the occupants about the use of supplemental heating and cooling systems and the extent of that use. This may be subjective information that can perhaps be verified by looking at fuel billing information.
2. Identify all appliances and fuel sources found in the building during the inspection process. If they are stored in the building, then it is likely they are used, if only on occasion.
3. Identify and record distribution systems used with each appliance. Usually the primary conditioning appliances are equipped with central distribution systems, and secondary appliances may be portable or space heaters. In any event, appliances used within a building will need to be assigned a percentage of load they are responsible for providing and a distribution system efficiency.

### **11.3.14. Maintain and Utilize Diagnostic Equipment in Investigation of Fuel Leaks**

Fuel leaks pose a fire or explosion danger, and should be identified and corrected as soon as possible. A combustible gas detector should be used in locating and quantifying natural gas and LP leaks, and you should not just rely on your sense of smell to identify fuel leaks. Even small

leaks should be repaired, because leaks never correct themselves and usually become more significant with time. Combustible gas detectors should be used in accordance with manufacturer's operating instructions, and a copy of the operator's manual should always accompany the equipment on-site.

1. Activate the detector in clean ambient air and establish an audible response rate of about one click per second.
2. Begin in the area that fuel enters the building and "sniff" around gas meters, fuel lines, unions, shut off valves and open gas valves. Listen for an audible response that increases from the benchmark of one click per second. The click rate will increase as the sensor approaches higher concentrations of combustible gas. The audible response is relative and does not identify quantities of gas. Some detectors are equipped with a series of lights which do identify concentrations and some detectors have an audible siren that responds to a factory-established level of fuel that approaches the explosive level.
3. If significant leaks are identified—or if gas or propane odor is strong—shut off corresponding gas supply valve and ventilate the area by opening windows or doors to the outdoors. When gas odors are strong, do not operate any electrical appliances or turn on light switches until ventilation has been provided and the concentration of gas has been successfully diminished.
4. The fuel vendor is to be notified when significant gas or propane leaks are identified by the detector or by the strong smell of gas. The gas supply valve may need to be locked out or the appliance red tagged for safety reasons, and the liability of doing so should rest with the fuel vendor.

### **11.3.15. Conduct a Water Heating Appliance Evaluation**

Domestic water heating is usually provided in one of three ways:

1. In a specific zone of a boiler,
2. In a separate combustion appliance, or
3. An electrically heated system.

The inspection of domestic water heating systems should include the combustion processes, insulation values, water temperatures and verification of temperature/pressure relief valves.

1. Measure water temperature coming from the tank by running a faucet in the home for a couple minutes and measuring the temperature of the water. Water temperatures should be in the range of 115–120°F. Adjustments can be made to the thermostat, with customer approval. Occasionally customers prefer a higher temperature for disinfecting diapers, some dishwashers, etc. but higher temperatures can cause severe burns, especially if children are in the household.
2. Inspect the insulation of domestic water systems. Hot water tanks should have external insulation if located in a cool area of the building and supply and return water lines

should be insulated to prevent heat loss and condensation on pipes during cooler weather. Electric water heaters benefit greatly from external tank insulation because of the cost of electricity. Gas systems should be insulated unless the manufacturer states otherwise. NOTE: External insulation should not be placed on the top of gas or oil fired water tanks, as flue temperatures may pose a fire hazard.

3. Operate combustion appliances and identify flame rollout, soot deposits, or scorching of the appliance.
4. Inspect the combustion chamber of gas and oil systems. The chamber should be free of soot, rust scale and debris. Identify any deposits on the burners that may interfere with proper combustion. Recommend oil nozzles be changed at least once a year and that deposits in the combustion chamber be vacuumed out.
5. Identify the presence of temperature/pressure valve. Recommend that this valve be opened once yearly to insure proper operation. Note: It is probably better to not open the valve as mineral deposits may prevent the valve from properly closing. Water tanks without temperature/pressure valves require retrofit or replacement. The temperature/pressure valve must be equipped with a drain line that safely directs any discharge downward and away from contact with any persons in the area of the heater.
6. Sediment collected in the water storage tank should be flushed out at least once a year. Here again, it is probably better to not open the drain valve of the tank unless a replacement valve is available, as sediment will likely prevent the valve from properly closing.

### **11.3.16. Identify the Type and Components of Cooling Systems**

Several types of air conditioning systems are available, depending on the geographical location of the home and the air conditioning needs.

1. Evaporative coolers work well for conditioning homes in warm dry climates, by simply adding moisture to the air and delivering large volumes of air to the living space. Windows need to be open when cooler is running, to exhaust unconditioned air and prevent creating high air pressures within the building.
2. Central air conditioning is often a split system, meaning the compressor and condensing coil are located outdoors where they can shed heat. The evaporator coil is located in a plenum of the homes ductwork.
3. Room air conditioners work well to cool a small area of the building and are usually portable and mount in a wall or window.
4. Mini-split air conditioning systems are an option for homes that do not have a central distribution system or have a difficult to cool space. The condensing unit is located outdoors with an evaporator coil and fan located in each room to be conditioned. The evaporator cabinets are typically located on an outside wall to facilitate the connections for refrigerant tubing, electrical cabling, and condensate removal. If located on an inside wall, condensate must be pumped to an appropriate drain.

5. Heat pumps often resemble a split system in that the compressor and condensing coil is located outdoors and evaporator and fan are located indoors. Heat pumps are sized to the cooling load of the structure, so that auxiliary heat (usually in the form of electric resistive heat) may be needed in some areas to provide adequate heating at outdoor design temperatures. Fossil fuel furnaces require an additional control kit to ensure the heat pump and fossil fuel appliance do not run at the same time.
6. “Gas pack” units are single-unit systems mounted on the roof. Since they are outside the envelope, they do not require a venting system, so there is no need to worry about carbon monoxide leaking into the living space.

### **11.3.17. Provide a Maintenance Inspection of the Cooling System**

Regular maintenance of cooling systems is important for maintaining the energy efficiency, comfort performance and indoor air quality. Unfortunately annual cleaning and inspection of AC units is often neglected because they can be hard to get at when encased in the supply plenum of a heating system. If the airflow across the evaporator coil is restricted by dirt or obstructions, the temperature will likely be out of the range recommended by the manufacturer. If the temperature drop across the evaporator coil is not between 18 and 20°F, then an inspection of the coil may be warranted. An inspection of the air distribution system should be made before attempting to inspect the evaporator coil itself.

1. Inspect and clean or replace air filters every one to two months when appliance is operated. Most air conditioning systems have barely enough air—or less than the minimum airflow—when filters are dirty and restrictive. The likelihood of the evaporator coil becoming dirty is very low if the filters are maintained on a regular basis.
2. Inspect the evaporator coil for dirt and obstructions at least every other year. A self-rinsing evaporator cleaner can be sprayed on to help loosen any dirt that may have accumulated. Condensate from the system operation will rinse cleaner from the coil. Again, most AC units cannot tolerate restriction to airflow without sacrificing efficiency and comfort.
3. Condensates collect in areas where molds and bacteria could grow undetected until the air quality of the building is compromised. As often as the evaporator coil is inspected and cleaned, so should condensate pans and collection systems. Water left standing in the condensate collection system for a season is an invitation to potentially dangerous microorganisms. Fungicides are routinely used in cleaning condensing pans and drains. Along with the condensate pan, the condensate trap should be blown out. Fungicide treatment will aid in preventing the trap from becoming plugged.
4. Condensing coils should be routinely cleaned of dirt and foreign debris. As these are usually outdoors, leaves and lawn trimming can often become trapped in the coil, reducing its ability to disperse waste heat. A wetting of the condenser coil with condenser coil cleaner should be followed by a blast of rinse water from a garden hose on an annual basis. This is necessary to keep the condenser coil clean.

5. Electric motors should be lightly oiled—as required—and fan belts should be inspected and replaced if showing any wear. Fan blades in the condensing section should be inspected to ensure no cracks have developed in the aluminum paddles.

### **11.3.18. *Identify the Tools and Products Used and Perform a Cleaning of Cooling Systems***

Cooling systems require some specialty products for cleaning and routine maintenance. The coils are usually copper tubes with aluminum fins that transfer heat very readily, but are delicate and can be bent easily. Dirty and bent fins will restrict airflow, so it becomes important to effectively clean fins, and straighten fins that are misshapen with a “fin comb.”

1. Brush off dirt and debris from the surface of evaporator and condensing coils.
2. Use a spray cleaner formulated for cleaning the copper and aluminum components of the air conditioning system. The inside coil should be sprayed with a self-rinsing coil cleaner.
3. Rinse the cleaner off the outdoor coil with a forceful stream from a garden hose. The hose should be held at a 45° downward angle to the face of the coil so dirt can be forced through the multiple sections of tubing.

### **11.3.19. *Record Results of Cooling System Inspection***

Once the cooling system inspection has been completed, information that has been gathered should be recorded. This information will identify the system for referencing specifications and replacement parts, as well as describing the work proposed for servicing or improving the performance of the system.

1. Record the model number and the serial number. The Btu rating of the appliance is usually coded in the model number, and it is the Btu rating that will determine what should be specified as appropriate airflow across the evaporator coil and whether the appliance is appropriately sized for the building. Air flow required across the evaporator coil in an air conditioning system is 400 cfm per ton of cooling, but may benefit from as much as 450 cfm per ton in a low humidity environment.
2. Record the temperature drop measured across the evaporator coil. This should be 18 to 20°F if the system has been running with temperature and humidity normalized in the conditioned space normalized.
3. Identify the distribution system used to deliver conditioned air to the living space. Duct leakage, duct design, filter replacement sizes, areas of the building serviced by ductwork and any design difficulties in establishing convective flow to the living space should be identified. Identify any ductwork that exists outside of the conditioned area and describe duct insulation values.

4. Identify measured airflow across the evaporator coil, as tested with an air flow meter Flow Plate, or duct blaster. Indicate plenum pressures as measured with static pressure probes for both the supply and return system.

## **12.0 Inspection and Diagnosis—Appliance Venting and Vent Pressure**

### **12.1. Scope**

The appliance vent inspection and pressure tests are conducted to insure the safe operation of all vented combustion appliance. This inspection should verify that the vent system is properly designed, installed, maintained, and that flue gas will not spill or leak from the system. The system inspection should also verify that the system is safe from fire issues and premature deterioration.

### **12.2. Tools and Materials**

Flashlight with drop cord, mirrors, drill and ¼" drill bits, differential manometer, vent sizing tables, tape measure.

### **12.3. Sequence and Procedures**

#### **12.3.1. *Identify all Ventilating Appliances to be Tested***

Vent inspections should be completed on all vented appliances, including sealed systems, power vented appliances, fan-assisted and atmospheric draft appliances. Pressure testing should be conducted on all atmospheric draft, fan-assisted, and power-drafted appliances (Category I).

#### **12.3.2. *Inspect Venting system for Design, Maintenance, and Safety***

Vent design should be in strict compliance with the manufacturer's specification. This is especially important in the case of high efficiency condensing appliances and motorized power vent systems. All other residential combustion vent designs will be specified by National Fire protection Association (NFPA). Vent design standards are complicated, and references should be consulted when designing a new system or troubleshooting a set of existing problems. The total vent system, from the breach of the appliance to the very termination should be visually inspected.

1. Inspect the vent connect pipe to the breach of the appliance. There should be no reduction in vent diameter size from that of the appliance breach. It is however acceptable for the vent connector to increase slightly in size. If the appliance breach is 5 inches in diameter, then a 4" vent connector is not allowed. A 6" vent connector may be allowed.
2. The pitch of a vent connector should be no less than ¼" per foot, rising away from the appliance. If an appliance is 6' from the vertical chimney, the vent connector must have a minimum rise of 1.5".
3. A gas vent should be constructed of double wall B-vent so as to maintain a temperature that helps prevent condensation and corrosion of the vent system. Vent connectors for fan-assisted natural gas and LP appliances should also be constructed of B-vent to reduce potential of condensation. Oil vent connectors and draft hooded gas appliance

vent connectors are often single wall-galvanized pipe for short distances, because the flue gas temperatures are usually well above the condensing temperature range. Solid-fuel vent pipes should be constructed of insulated or triple wall stainless steel material, wherever the vent pipe is located outside of the conditioned living space.

4. B-vent is not rated to be used out of doors except where it exits the roof to prevent condensation of flue gases within the vent. If located outside, it should be enclosed in an insulated chase.
5. Natural gas and LP gas horizontal vent connectors should be no longer than 1½ times the diameter of the vent (in feet) to reduce the potential of condensation in the flue. For example, if the vent connector is 4" in diameter, the maximum horizontal distance of the vent connector pipe to the main vent is 6'.
6. Outside masonry chimneys (those having one or more sides exposed to the outdoor ambient temperature) should not be used with fan-assisted gas appliances to eliminate the probability of condensation of flue gasses.
7. Vent connect pipe should be locked together at each connection with either a manufacturer's locking system or with 3 self-tapping screws.
8. Vent connect pipe should be supported with strapping or other non-flammable material so that it is stable and resists movement.
9. Inspect for corrosion, either in the form of rust or powdery white residue. Signs of this indicate probable condensation or moisture damage and replacement of damaged components is required.
10. Inspect the chimney or vent termination from the outdoors. The system should rise 3' higher than any roof system it penetrates and should be 2' higher than any objects within a distance of 10'.
11. Where two appliances are vented together into the same chimney or vent connect pipe, the connect pipe of the smaller of the appliances (in Btu) should be above the larger, or positioned closer to the chimney.
12. All power-vented appliances should follow sizing and termination guidelines as per the manufacturer of the power vent.

### **12.3.3. Identify All Un-Vented and Under-Vented Combustion Appliances**

Unvented combustion appliances (with the exception of the oven/range) should not be used within the residence. Ovens and ranges, when unvented, should be used in combination with an exhaust fan located in the immediate vicinity.

Under-vented combustion appliances are those appliances where the vent system is not substantial enough to completely handle the exhaust products. The distinguishing characteristic of an under-vented draft-hooded appliance is the spillage of flue gases that occur after 60 seconds of operation. Fan-assisted and power-vented appliances have draft proving pressure

switches that will prevent operation in the event of inadequate venting. Spillage is a typical occurrence when:

1. Appliances have long lateral runs of vent pipe, or are constructed with 3 or more 90-degree elbows.
2. Vent systems are serving two or more appliances in tandem.
3. Chimneys are constructed of unlined masonry material.
4. Vent designs do not provide termination higher than other objects in the immediate vicinity. Wind can cause a positive pressure at the termination of the vent pipe, which can prevent flue gases from escaping.

#### **12.3.4.      *Inspect Appliance Vent For Obstructions and Design***

1. Vent systems require periodic inspections and cleaning, but most never receive any preventative maintenance until a problem develops. It is recommended that oil-based and gas appliances be serviced at least once a year, or following manufacturers recommendations.
2. Remove the vent connect pipe from the chimney and inspect the inside of the vent system for cracks in the tile liner and any obstructions (including masonry debris that may have corroded from the sides of the chimney).
3. Inspect for soot and creosote deposits from solid fuel appliances in appliances and fireplaces.
4. With a mirror and drop light, inspect for foreign debris such as leaves, dead birds, etc. that may have fallen down the open chimney.
5. With a mirror, inspect the inside length of the vertical vent, to ensure that it is free of objects and that daylight can be seen from the top—straight through to the vent connect opening.
6. Inspect the vent connector for signs of corrosion.

#### **12.3.5.      *Inspect Combustion Appliance Vent Systems For Required Clearance to Combustible Materials***

Combustion appliance vents are manufactured for different fuels, with different materials and to different specifications. One of the most important specifications is the clearance or distance the vent pipe must be positioned for any combustible material. The distance between a vent connect pipe and a combustible material, such as insulation or a framing member of the building is specified by NFPA, but in many localities, local construction codes have superseded the National fire code. It is recommended that home performance inspectors consult with local codes officials for amendments to the national codes.

1. Single-wall metal vent material should maintain a clearance of 6" to any combustible materials, except on wood and oil which requires 18" the UMC.

2. Type B metal vent material—when used with an appliance that incorporates a draft diverter—must maintain a minimum clearance of 2" from combustible materials.
3. Vent connect pipes are not to be insulated unless the insulation was installed by the manufacturer. It is important that the vent connect pipes be readily accessible for inspection, which is why they are not to be covered with insulation, or run through zones of the building that cannot be accessed for inspection.

### **12.3.6. Provide a Vent Pressure Test**

The vent pressure test is an analytical expression of the strength of the vent system, expressed in inches of water column—or Pascal of pressure. It is required on all atmospheric and fan-assisted appliances, but not required on power-vented or sealed combustion. The vent pressure of atmospheric appliances is dependent on the pressure difference between the outdoor and the indoors, which is greatly influenced by air temperatures. It is assumed that a reasonable prediction of warm weather vent pressure can be made from a cold weather test, and that cold weather vent pressures can be predicted from warm weather testing.

1. Drill a ¼"-hole in the vent connect pipe of each atmospheric combustion appliance. This hole should be located between the last opening in the vent connect pipe (barometric damper, spillage port, etc.) and the chimney—approximately 12–24" from the top of the draft hood, in a straight section of pipe. If two appliances share the same vent connect pipe, then a hole will need to be drilled for each appliance. In this case, test holes should be drilled between the spillage port of each appliance and the location where the two vent connect pipes merge.
2. Activate the carbon monoxide detector in the combustion appliance zone, as appliances with weak or no draft will dump flue gasses into the zone.
3. Using a differential manometer, measure the pressure in the vent pipe, with reference to the combustion zone. Be sure to keep the manometer probe perpendicular to the stream of flue gas for this measurement. Acceptable draft levels are dependent on outdoor air temperature at the time of testing. When outdoor air temperature are 30°F or less, a combustion vent must have a minimum vent pressure of -0.02" of water column (-5 Pascal). When the outdoor air temperatures are between 30 and 80°F, a vent pressure of 0.01" of water column (-2.5 Pascal) is required. For outdoor air temperatures above 80°F, a pressure of 0.005 (1.25 Pascal) is required. Insert the probe into the center of the vent and observe the reading. Remove the probe and record the reading.
4. On completion, wipe the vent area where the hole was drilled and place a piece of 2" UL 181AP pressure sensitive metallic tape completely around the vent so that the ends overlap. Use a rag to press the tape tight and seal it around the vent.
5. Record the vent pressure for each appliance, and be sure to record the outdoor air temperature at the time of the test.
6. Where two or more appliances share a vent connect pipe or chimney, first test the vent pressure of each appliance operating singularly, and then test the appliances operating

together. If the chimney is too small to handle all the flue gas being produced by the two appliances collectively, the vent pressure in one or both of the appliances may be reduced. If this is the case, record the testing conditions and results.

Preferred results include:

- A draft reading of -0.02"wc (or more negative) if the outside temperature is below 30°F
- A draft reading of -0.01"wc (or more negative) if the outside temperature is between 30–80°F
- A draft reading of -0.005"wc (or more negative) if the outside temperature is above 80°F

### **12.3.7. Conduct Vent Spillage Tests**

The vent spillage test checks to ensure there's a draft that is substantial enough to exhaust the flue gasses produced by an appliance. This is based on the ability of the appliance to heat the vent system, and also on the venting design characteristics of the system. Some appliances will establish draft almost instantly, while others never really establish a dependable draft. Only atmospheric draft appliances need be tested. Power draft, fan-assisted, and sealed combustion appliances do not require spillage testing because of a draft proving switch being incorporated into the safety circuit of the appliance.

1. Activate each combustion appliance, timing the duration required before diagnostic smoke placed at the vent spillage (or the dilution air opening—or at the barometric damper) is drawn into the vent system.
2. Use diagnostic smoke around the entire perimeter of the draft diverter. Verify that there is no spillage occurring by moving your hands around any vent opening and feeling for heat or moisture.
3. Measure the time required to establish the draft for each appliance and record.



## 13.0 Inspection and Diagnosis—Building Envelope

### 13.1. Scope

Identification of framing and envelope characteristics can aid in locating paths of air leakage, material degradation, and structural problems. Moisture problems both inside and outside the building often manifest themselves first on the building envelope. The purpose of this inspection is to identify framing techniques used in residential construction so that you can quantify the options for retrofitting and/or remediation work on the envelope. Identifying framing characteristics is also important for determining heat loss through the envelope, because the frame makes up a percentage of the shell. The frame itself has an ‘R’ value that will be different from that in insulated cavities.

### 13.2. Tools and Materials

Blower door, diagnostic smoke.

### 13.3. Procedure

#### 13.3.1. *Identify the Framing Style Used in Construction*

To perform a meaningful inspection, and to develop a retrofit strategy, you’ll need to understand the framing design characteristics. There are certain elements that a retrofitter needs to be aware of such as roof or post wind-braces and fire-stops (for example, when filling walls with insulation, it’s important to know where the fire-stops are).

Your inspection will have to access every part of the building. There are common things to look for depending on the type of building system used:

1. Platform construction: As walls are framed, each floor becomes its own wall system with regards to air movement. This is common and if done right, generally has no intrinsic problems. Look for anything unusual that might indicate “creativity” on the part of the builder.
2. Balloon framing: The largest issue in balloon framing tends to be the lack of fire-stops. This creates air cavities that often span the sides of the building, linking the basement directly to the attic. Air that comes into the wall system from the attic can be distributed anywhere in the building. Blowing insulation throughout the entire wall system can sometimes be circumvented by capping these wall cavities—insulating within the very top of the wall system, and then sealing over this space with metal flashing that’s held in place by a thick bead of silicone caulk and heavy staples.
3. Platform construction: As walls are framed, each floor becomes its own wall system with regards to air movement. This is common and if done right, generally has no intrinsic problems. Look for anything unusual that might indicate “creativity” on the part of the builder.
4. Post and beam construction: The points where the posts and beams meet the outer skin most often provide for vulnerabilities in thermal sealing.

5. Stress-skin panel construction: This design is characterized by foam-filled modular panels designed for high energy efficiency. Be sure you understand how the modular panels are connected, and the sealing efforts used to ensure that air doesn't breach the envelope.
6. Cape Cod-style construction: This design is characterized by the knee-wall space underneath the lower roof structure. These tend to be sealed spaces and insulated from the outside, and they also tend to be unconditioned spaces. These spaces are often directly connected to the band-joint areas in the floor/ceiling below. Sometimes in this situation, air can move freely from one side of the building to the other, traveling between the joists of the floor/ceiling framing. Warm air from the conditioned space will heat up those floor/ceiling cavities, and create a convective loop that pulls heat from the conditioned spaces. All air leakage routes and bypasses must be identified and closed off.

### **13.3.2. Determine Framing Techniques and Characteristics Incorporated Into a Structure**

The key thing is to shut down all air movement in the floor/wall systems throughout the building. This takes a clear understanding of techniques used when building was constructed. Newer California homes are more complex than older homes and even though they may have much more building insulation, they may not perform well. Many of the complex architectural features are very hard to insulate effectively.

1. Take a close look at the outer corners of the wall system. Sometimes there is quite a bit of wood used in the building of corners, and this mass must be insulated somehow from the conditioned area.
2. Make sure you understand how the interior walls intersect. Look for air compartments that might be generated by unusual framing techniques. Interior wall partitions are sometimes open to the basement. Use diagnostic smoke in the basement to determine whether this is the case.
3. Look at the upper floor's band-joint cavities, and especially the point where it intersects the outer wall. Leakage in this area affects the entire wall system. The key thing is to shut down air movement throughout the building.
4. Be specific to identify the inner dimensions of the frame. How deep are the wall cavities?
5. Pay particular attention to dropped ceilings or soffits in kitchen spaces. This technique allows for spotlights to be embedded in the ceiling above the kitchen, and because there is no air barrier, heat from the kitchen interacts with the space above through air bypasses.
6. Check for pocket doors. Where the pocket door cavity meets the wall, air moves freely between the interior of the room and the inside of the wall system. This can be significant when planning for insulation retrofit project.

7. Inspect any attached buildings, garages, porches, and additions may result in air leakage into the conditioned space.
8. The wall studs of a dormer often start down in the floor system below it, and this can create air movement routes and bypasses for uncontrolled ventilation, and these must be identified.
9. Masonry chimneys should always have a gap between the masonry and the wood framing, and this gap can extend the entire length of the building. This can create convective air movement that must be capped at the top. Once all air movement is stopped, then the air itself becomes insulation. Seal the top of this gap using metal coil stock and flashing stapled to the floor frame.

### **13.3.3.      *Inspect the Building Envelope For Continuity***

Every space in the building must be classified as conditioned or unconditioned space, and conditioned spaces should always be insulated and sealed from unconditioned space. Infrared scanners can easily identify problems and deficiencies within the building envelope.

1. Look at the building under static conditions first in order to get a sense for how the thermal boundary works. Then put the building under pressure for a few minutes, and use an infrared scanner to determine where air leakage occurs.
2. Wrap-around porches often have a 3–4' space between the ceiling and the porch roof deck, and often there is no air barrier between the unconditioned space and the conditioned spaces within the house.

### **13.3.4.      *Identify the Building Materials Utilized in Establishing the Building Envelope, and Any Degradation***

All building materials in the envelope contribute to the overall thermal performance, so you must really know about the components of the envelope. You can't just make assumptions about the wall systems, and especially when it comes to performing heat-loss calculations and determining retrofit options. You may have to figure out a relatively unobtrusive way to get into these areas.

- Check for sheathing underneath the siding.
- Check for plaster underneath the sheetrock.
- Check for lathe underneath the plaster.
- Check for an air space in the center of brick walls.
- Check sill plates where they come into contact with masonry.
- Access under the roof and look for degradation of the roof deck.
- Look for any other symptoms of building material degradation.

### **13.3.5. Evaluate Ventilation Systems that Penetrate the Building Envelope**

It is critical that any appliance requiring exhaust be ventilated to the OUTSIDE of the building envelope. Find out where mechanical ventilations systems are and where they terminate.

1. The make-up air for a combustion zone needs to be considered. For slab-on-grade buildings, combustion appliances tend to be placed within or above the living space, and there needs to be a provision made for make-up air to that space. The standards that we need to meet are based on the Btu capacity of the appliance. So the size of the appliance determines the amount of make-up air that is required and your inspection should address whether enough make-up air is being supplied.
2. Range-hoods need to have exhaust systems should never be vented into an attic or a crawlspace.

### **13.3.6. Identify and Correct the Causes of Ice Damming**

Ice damming is irrelevant in most of California but can be a problem in snowy mountain areas. It occurs in colder zones wherever warm air is pulled into an attic and (when combined with a lack of insulation) warms up a snow-covered roof deck. As melting water meets the eaves of the house, it re-freezes and starts to build up ice along the eaves. There are convective reasons and conductive reasons for this, and the situation needs to be analyzed to figure out what is going on. If left untreated, eventually this ice will build up and perhaps even back-up underneath the shingles.

1. Get up above the living space to examine and verify the integrity of the air barrier and the thermal barrier.
2. Heat loss by convection into the attic can be identified using diagnostic smoke.

### **13.3.7. Determine If Attic Ventilation Has Any Impact on the Conditioned Areas of the Building**

There should be no direct interaction between air in the attic and the conditioned space below. In hotter climate zones, attic ventilation is even more important, to keep the attic from heating up too much. Heat that builds up in the attic will radiate into the living space. Attic ventilation should always be designed to pull air from the outside. Don't use ventilation to solve problems with the integrity of the air/thermal barriers in the envelope.

1. There must be a balance between the air that come into the attic and the air that leaves the attic. Typically, air should be entering low in the attic at the edges or soffits, and be exhausted closer higher at the ridge.
2. Attic ventilation can often contribute to convective heat losses in the attic because the pressure that drives the ventilation system creates a negative pressure in the attic zone. Then, if there is an opening to the living space (for example, around a chimney) the negative pressure will pull warm air into the attic.

3. When a vapor barrier exists or if half of the vents are high and half are low, there should be approximately one square foot of ventilation opening for every 300 ft<sup>2</sup> of attic space. Where no vapor barrier exists, there should be 1 ft<sup>2</sup> of ventilation opening for every 150' of attic space.
4. Note that in hotter zones, a light colored roof can have a greater impact on the air temperature in the attic than ventilation.



## 14.0 Inspection and Diagnosis—Thermal Boundary

### 14.1. Scope

This inspection involves evaluating the performance characteristics and overall integrity of the thermal boundary. You'll examine the thermal boundaries throughout the building envelope, including areas typically hidden from view. It is important to be as precise and comprehensive as possible, and remember that separate components with different properties must be documented as separate entries and cannot be aggregated.

There are 2 primary goals: To accurately model space conditioning loads, and to document opportunities for performance enhancements.

Use a standardized approach such as starting from the entry side of the building and moving clockwise to gather all wall, door and window information. Be sure to include the orientation of each (N.S.E.W.). Then go to the attic and floor areas. All areas are to be modeled with reference to either a building zone, i.e. wall to garage, ceiling to attic, or referenced to the outside – ambient or below grade.

Ask customers about their comfort with respect to various rooms or areas of the building. Look for relationships between seasonal discomfort and surface areas and the orientation of window glazing, uninsulated walls and ceilings

### 14.2. Tools and Materials

Pad and paper (or calculator), infrared scanner, drill and bits, drop cord, flashlight, tape measure, siding removal tools, ladder, personal safety equipment.

### 14.3. Procedure

#### 14.3.1. ***Define and Document All Existing Thermal Boundary Components***

1. Systematically move through the building making a list of thermal boundaries that will be included in your overall evaluation.
2. Use that list and this procedure to make sure you don't miss anything.

#### 14.3.2. ***Collect Relevant Building Dimensions to Determine Overall Square Footage of Thermal Boundary Components: You Must Be Accurate to Within 10%.***

1. Measure the depth of insulation in wall, ceiling and floor systems, to the nearest ½", with the use of a probe. If a thermal boundary has more than one insulation level (that is, an attic has 6" of insulation in some areas and 9" in other areas), record the areas as two separate areas. This will be important in developing a precise workscope proposal.
2. Measure windows and doors to the nearest ¼' length/width and measure walls, attics and floors to the nearest foot in each direction. In addition to measuring surface areas,

document associated material depth and properties i.e., *6" wall with 4" of high density cellulose, ½" drywall, ½" sheathing, etc.*

- Walls—Identify the orientation of each; North, South, East and West
- Doors—With orientation (N.S.E.W.).
- Windows—With orientation (N.S.E.W.). Windows should be identified by construction material, number of glass panes and any special treatments. Example: 30 ft<sup>2</sup> of single glazed with storm window, south facing. If the window manufacturer and model number can be identified, there may be specifications on the tested U-value and Solar heat gain coefficient available from the National Fenestration Rating Council, provided the windows have been rated.

### **14.3.3. Perform a Visual Inspection on Each Thermal Boundary Component**

1. Define and document the collective insulation value (U-value) of each thermal boundary component. (existing insulation + building materials = collective insulation value)
  - Document the types, dimensions and condition of existing insulation materials.
  - Document the location and dimensions of any thermal boundaries lacking insulation or containing damaged insulation.
  - Document the placement of any existing (or proposed) moisture and vapor barriers.
  - Document existing or proposed ventilation strategies for attics, vaulted ceilings, and floor systems.
  - Document existing clearances in areas where insulation surrounds combustion vents, recessed lighting and/or heat sources.
  - Document energy performance characteristics (R-Values) for the building materials of each thermal boundary component.
2. Investigate all envelope areas that show signs of warping, paint peeling, water staining, or discoloration.
3. Check interior surfaces with a pin type moisture meter and investigate further any area showing a moisture content exceeding 12%.
4. Access any suspect areas to examine the condition of the insulation. Note remodeling efforts that might have created new partitions and spaces that hide the original details of the building. You'll need to investigate these modifications to identify breaks in thermal boundaries that are not obvious. Building additions can create water-related problems that did not previously exist. By adding more roof surface, connecting joints, flashing details, and using dissimilar building materials, opportunities for water and air leakage increase.
5. Calculate the square foot of damaged or ineffective thermal boundary and record.

#### **14.3.4. Conduct an Infrared Inspection of the Entire Thermal Boundary**

Conduct an infrared inspection of the entire thermal boundary from the inside (there are too many variables influencing exterior inspections). Confirm the presence or absence of insulation in areas that are inaccessible for physical inspection.

1. Always read the operator's manual for the infrared equipment being used.
2. Determine temperature difference across the thermal boundary. 15°F or greater is preferred, and will provide better imaging.
3. Identify image variations between the building frame and frame cavities.
4. Identify image variations within the frame cavities.
5. Map all areas that appear to deviate from the known reference properties.
6. For large wall areas that are not directly accessible, find a place where you can drill a small sampling hole (in a closet or underneath outer siding that can be covered easily). Then use a probe and a flashlight to examine the contents and condition. This will serve as a reference point for comparison purposes.
7. Investigate areas appearing to be anomalies in the thermal boundary. Identify and document any voids or deviations in the thermal boundary.
8. Identify and document any obstructions to installing insulation in un-insulated areas.

#### **14.3.5. Record Results and Recommendations on the Attached Sheets**

Make recommendations to insulate walls and ceilings that lack effective insulation value. Make recommendations for window treatments as response to both summer and winter seasonal discomfort.

1. High-density cellulose insulation should be considered for uninsulated sidewalls.
2. High-density insulation should be considered for rim joist cavities between the first and second floors.
3. Attic kneewalls should be insulated in a manner that prevents airflow through the insulation materials, i.e. rigid board, wet spray cellulose, 2 part urethanes.
4. Attic insulation should have a nominal performance rating of R-38.
5. Floored attic areas should insulated with high-density cellulose beneath the floor, if possible.
6. All air leakage into insulation barriers, i.e. recessed lighting fixtures, electrical outlets, plumbing and electrical penetrations, etc... should be air sealed.
7. Attic areas should be ventilated to reduce moisture and heat buildup.
8. Crawl spaces associated with the earth or foundation should only be ventilated when outdoor air is dry (below 50% humidity). Otherwise crawl space areas should remain unventilated.

9. Radiant Barriers are reflective surfaces, positioned to intercept the flow of radiant energy. A roof, heated by the sun, which in turn radiates heat toward the attic floor and warms the surfaces of the insulation and exposed frame, is an example of a radiant source that can transfer heat to the living area, even though the attic is insulated. Radiant barriers are typically used to minimize summer heat gains to air conditioned homes by reflecting radiant energy back toward the roof system. Radiant barriers must be highly reflective, i.e., aluminum or mylar, and that there be an air space on both sides of the barrier. If the reflective surface becomes dusty or dirty, the material will absorb much more energy, and without an air space, the radiant properties are lost and the barrier transfers its captured energy by way of conduction. Foil faced polyethylene is an example of a material that is a good radiant barrier because of the polyethylene air spaces between 2 layers of highly reflective foil.

Some typical locations for a radiant barrier installed in an attic are:

1. During construction the barrier is installed on top of the rafter, before the roof deck is installed. The barrier is allowed to drape a few inches below the roof deck, within the rafter cavities.
2. Radiant barriers can be installed on the attic floor, over the top of the insulation. This will reflect energy back toward the roof. The attic will remain cooler and the barrier more effective if ample attic ventilation exist between the radiant barrier and the roof deck. An air space is required between the barrier and the insulation, to avoid conductive gains from the hot attic toward the insulation. Do not cover recessed lighting fixtures, exhaust ventilators or any fixtures that produce heat.
3. The barrier can be installed on the bottom of the rafter or top chords of the roof trusses. A minimum airspace of 1" between the barrier and the roof deck is required.

## 15.0 Inspection and Diagnosis—Blower Door Test

### 15.1. Scope

The blower door is a calibrated fan that's capable of moving enough air (up to 6,000 cfm) to create a significant pressure within a typical residential building. A digital manometer is used to measure building and fan pressures when calculating airflow. By measuring the amount of pressure created within the building – as well as the amount of air moving through the calibrated fan - an airflow or air leakage rate can be established. The industry standard for leakage measurement is “cubic feet per minute at 50 Pascal – or cfm 50” The value of this diagnostic test is that a flow rate of the building can be established, and the test can be duplicated after remediation has been performed, so as to evaluate the benefits of work performed. In addition, leakage points can be easily identified under the pressures created by this test.

### 15.2. Tools and Materials

Blower door, a digital manometer, an infrared scanner, and diagnostic smoke generator.

### 15.3. Procedure

#### 15.3.1. *Configure the Building Envelope for Pressure Testing*

Accurate evaluation of the building airflow / leakage rates requires the building to be properly configured for pressure testing. It is important that the pressure boundary and the thermal boundary be identified, and that the test reflects the leakage across these boundaries. If the boundaries are ambiguous (for example, when the whole house could technically be considered one appliance zone), then a record of the configuration should be made so that subsequent tests can be conducted under similar conditions for comparison purposes.

1. Identify the pressure and thermal boundaries. These two boundaries should be in perfect alignment for either to be effective. Air moving through insulation reduces or voids the thermal value. Determine if zones outside of the living space, (i.e. enclosed porches, mudrooms, attics, basements, etc.) can be closed off as part of the pressure/thermal boundary or not. If they can be closed off, then entries between these zones and the living space should be closed.
2. Identify areas of the envelope that are unintentional holes in the pressure boundary, i.e. plaster missing from the ceiling, broken windows, missing scuttle hatch to the attic or an open fireplace damper. Make temporary repairs of any areas that are unintentional holes that would skew the results of pressure testing.
3. Configure the building into “winter mode”, meaning all primary windows and doors are closed and all exterior doors to attached zones such as garages enclosed porches, attics, etc... Passive vents such as fireplace dampers or whole house fans should be in the closed position.

### **15.3.2. Configure the Internal Building for Pressure Testing**

Interior configuration of the building involves establishing the zones to be tested, and controlling all mechanical and combustion equipment.

1. Open interior doors to bedrooms, bathrooms, offices, walk-in closets, etc. so as to expose each room to the direct influence of the blower door, which is usually located in the central living space.
2. Discontinue the use of any ventilation/exhaust appliances during the blower door test. It is not necessary to configure the exhaust vent, other than to make sure the appliance is turned off.
3. Turn off combustion appliances, by setting the burner to “pilot only” or setting the thermostat on stand-by. If combustion appliances happen to fire during a blower door test, dangerous flue gasses will enter the building and the risk of a house fire is elevated.
4. Check the position of air registers. Supply and return registers should be in the open position for whole house testing.

### **15.3.3. Select an Appropriate Location and Install a Blower Door**

Usually, a blower door can be installed in any convenient exterior doorway, but there are ways to improve the accuracy of the test under certain conditions, and with the least amount of disruption to occupants.

1. Select a passageway that goes directly to the outdoors rather than into an attached zone, such as a garage or enclosed porch. This avoids potential interactions that may exist between the zone and the living space being tested.
2. Select a passageway that is out of the wind or on the leeward side of the building. This will help to avoid erratic pressure readings caused by strong gusts of wind striking the fan head.
3. Select a doorway that is not in the middle of the traffic patterns. This will allow occupants the opportunity to enter and leave the building if necessary and provide you with access to your vehicle, should additional tools/equipment be needed.
4. Inform the occupants of testing requirements - including safety around the blower door and egress protocol.
5. Install doorframe, shroud and fan, leaving the fan head covered.
6. *For negative pressure testing of the building*, you’ll connect a digital manometer to measure the house pressure with reference to the outdoors, and also to measure the fan pressure with reference to the house interior.
7. *For positive pressure testing of the building*, reverse the fan position as the blower door fans are calibrated for one direction only. You’ll use the digital manometer to measure the house pressure with reference to the outdoors, and also to measure the fan pressure with reference to the outdoors.

#### **15.3.4. Conduct and Interpret a Blower Door Test**

The blower door test is usually conducted at an industry standard of 0.2" of water column - or 50 Pascal, if possible. If that pressure cannot be attained because of the building size or leakage rate, use the California "Can't reach 50" chart) to interpret the results. The pressure created will be uniform across the building envelope, placing identical pressures across all holes in the envelope. The total leakage of all the holes combined will be reflected in the amount of air that passes through the fan head at the established house pressure.

1. With the blower door installed and the fan head sealed, measure the pressure of the building with reference to the outdoors. There may be an existing stack effect or wind effect upon the building, reflected on the manometer when measuring house pressure with reference to outdoors.
2. Open the fan and activate the blower door fan, adding an additional 50 Pascal of pressure to the house.
3. Measure the pressure created across the fan when the house reaches 50 Pascal of pressure and interpret that fan pressure to cubic feet of air by means of a fan flow chart or a calibrated manometer.
4. Repeat the test to verify results and record air leakage rates as "cubic feet per minute at 50 Pascal." ( xxxxcfm<sub>50</sub> )
5. Determine the LBL or "natural" factor for the building, based on its climate zone, location, and number of stories above ground. The LBL factor represents "the stack effect," temperature, and wind impact on the building, and factors it into an interpretation of cfm at 50—to natural airflow. The 50 Pascal flow rate of the building is divided by the LBL factor to determine natural flow rate building (in cubic feet per minute). The LBNL natural factor is derived from the LBNL natural factor chart—usually located in the blower door instruction manual.
  - o Locate the zone you are in.
  - o Determine the building's exposure to wind by identifying anything that would buffer the building from direct wind.
  - o Identify the numbers of stories exposed above grade.
6. Measure the volume of the tested living space (in cubic feet). This will be required to convert cubic feet per minute to air changes per hour, which is also a means of measuring leakage rates and ventilation rates for a building.
7. Multiply the cubic feet per minute natural flow rate by 60 to determine the natural hourly flow rate of the building. Divide the results by the volume of the building to determine the building's air change per hour (ACH) rate.

### **15.3.5. Determine the Type of Test (Pressurization or Depressurization) Best Suited For the Building.**

Blower door testing, for the purpose of measuring air leakage rates and identifying leakage paths can be conducted in a pressurization or depressurization mode, however there are distinct advantages to providing a depressurization test. Use the “can’t reach 50” chart.

1. Infiltrating air will be easier to sense and create a more pronounced tactile sensation, which is important for diagnostics.
2. Infiltrating air of a different temperature will leave a distinguishable thermal image on the interior surfaces of the building envelope. This is important for infrared imaging.
3. Depressurization testing usually provides less discomfort to building occupants during cold weather inspections.
4. Pressurization tests may better represent the air leakage of buildings that are maintained at a positive pressure, via ventilation. In reality, most leaks in a building envelope are subject to wind pressure, wind direction, the location of the leak in the building, etc... and operate under different forces, at different times.
5. Pressurization of a building is effective as a diagnostic tool when using diagnostic smoke to locate leakage sites. If there is a fire in a woodstove, your only option is to test pressurized.
6. Testing under positive pressure may give higher leakage rates since back-draft dampers on the range, dryer, and bathroom exhaust fans will be blown open.

### **15.3.6. Utilize a Blower Door in the Evaluation of Air Sealing Needs and the Effectiveness of Installations**

The blower door is the ideal tool for locating air leaks through the manipulation of pressures across the building envelope as well as ductwork that may extend outside of the envelope. Tactile sensing of air leaks, infrared imaging, and the use of diagnostic smoke are the three primary diagnostic techniques. Infrared imaging is best done from the interior of the building, using negative pressure. Diagnostic smoke is best used while in the positive pressure zone - allowing the smoke to be drawn toward the negative pressure zone. This presents a better result, and prevents diagnostic smoke from being blown into the inspector’s face. Tactile sensing is best done from within the zone that has been placed under negative pressure. It is easier to sense infiltrating air than exfiltrating air.

1. Create a negative pressure within the conditioned area of the building and draw air of a different temperature across the envelope. Within a few minutes the incoming air will leave a thermal image on the envelope that is visible with infrared imaging. This diagnostic will identify warmer air from a hot attic or outdoor air that brightens the image, while cooler air from outdoors or an unheated zone will create a darker image. The source of the air leaks can often be identified by the location where the change in the thermal image is the most pronounced.

2. Create a negative pressure within the conditioned area of the building and position yourself outside of the envelope with diagnostic smoke. The smoke will be drawn toward the leakage site. This is an effective way to identify leaks between a garage or attic and the living space. Likewise, ductwork that is under negative pressure in the living space will draw the diagnostic smoke through leaks located outside of the living space, i.e. in the attic or crawl space.
3. Create a positive pressure within the living space and use the diagnostic smoke to identify air moving from the zone to an attached zone or to the outdoors. Subtle pressures of 10 Pascal or less are very effective for this diagnostic.
4. Create a positive pressure within the living space and use infrared imaging to identify warm, conditioned air moving to unconditioned zones such as the attic or garage.
5. Upon the repair of identified air leakage sites, perform a blower door test under the same conditions as the initial test and calculate the reduction of air leakage achieved by the installed measures.

#### **15.3.7.      *Ensure the Building and Systems Are Operational at the Completion of Blower Door Work***

Once blower door testing has been completed, an inspection of the building should be conducted and the building returned to its original configuration.

1. Re-establish all thermostats and controls for appliances that have been placed on standby for blower door testing.
2. The blower door may have extinguished standing pilots on appliances. Check all combustion appliances including ranges, ovens, water heaters, gas clothes dryers and heating systems to insure that pilot lights are still operational. Light any pilot lights that have been extinguished, and run each appliance through a complete cycle.
3. The building envelope should be re-established to the configuration of the occupant's preference. If windows were closed for blower door testing, they should be re-opened.
4. Balancing dampers and air registers that were opened for blower door testing, should be repositioned as they were originally.

Passive ventilators and dampers (for example, fireplace dampers that were closed for blower door testing) should be re-established to their original configuration.



## 16.0 Inspection and Diagnosis—Transition Zones

### 16.1. Scope

Transition zones are those unconditioned areas of the building that are attached to the living space. They are somewhat enclosed - so they cannot be considered outdoors, and they are often unintentionally open connected to the conditioned space. This makes them a transition zone where infiltrating or exfiltrating air finds a pathway. Obviously a thermal boundary should exist between the conditioned area and the attic, or crawl space, attached garage or porch roof system. A pressure boundary must also exist in these areas to control air leakage.

Many homes have attached porches where the building frame between the roof of the porch and the wall of the house is open to great amounts of air leakage. Leakage in this location can easily travel through the 2nd floor joist system to anywhere in the home, causing discomfort and moisture problems for the building materials, poor energy efficiency, and health threats from contaminated garages or crawl spaces etc. When this situation is noticed, it's important to determine how large the leakage path is, and what range of pressures it normally experiences. The answers to these questions should be determined before the building workscope is developed, because these may well be the most important areas of the building to seal for air leakage.

### 16.2. Tools and Materials

Blower door, Differential manometers, stem thermometers, drill w/ 1/8, 3/16 and ¼ inch drill bits, diagnostic smoke, infrared camera.

### 16.3. Procedure

#### **16.3.1. *Identify All Transition Zones Associated With the Conditioned Area***

The junctures between any transition zone and the conditioned area of the building can be a source of air leakage and are important to test. It is valuable to list the zones in an order for testing and record the results of each zone test.

1. Inspect the exterior of the building and identify all attached porches, garages, storage facilities, cantilevers and crawl spaces.
2. Inspect the interior of the building and identify any unconditioned rooms or additions, attics, and basements.

#### **16.3.2. *Inspect Key Junctures of the Building Frame For Air Leakage or Signs of Long-term Air Leakage***

1. The building frame is often the pathway for major air leakage within the building. A visual inspection often provides clues to this air leakage.
2. Examine the exterior of each key juncture for areas of discoloration of the siding, paint peeling, dirt and dust deposits along roof lines, facias and soffits.

3. Examine the interior of the building around doorways to attached zones, attic entries for dust and dirt deposits. Where possible, inspect the building frame for cobwebs and dust deposits, as these are signs of moving air patterns.
4. Where possible, inspect insulation for signs of discoloration, dust and dirt deposits that demonstrate airflow and filtration. Inspect along interior and exterior wall partitions, chaseways, plumbing and wiring penetrations.

### **16.3.3. Utilize the Blower Door in the Evaluation of the Building Frame For Air Leakage Paths**

1. As the building is placed under positive or negative pressure with the blower door, look for air leakage from transition zones to be drawn into the living space. Record all results.
2. Frequently, the larger leaks are *within* the building frame and will not be visually identifiable.
3. Configure the building into “winter mode,” with primary windows and doors closed - and all doors and openings to transition zones closed.
4. Disable any combustion appliances to prevent them from operating while performing this test.
5. Install the blower door in an entry between the living space and the outdoors.
6. Measure the negative pressure created within the building with a differential manometer established to measure the house pressure, with reference to the outdoors.
7. Depressurize the living space to negative 50 Pascal, and measure the corresponding fan pressure and flow.
8. With a separate manometer, measure the pressure of each transition zone, with reference to the outdoors.
9. If infrared imaging is an option - from within the living space, examine the building frame associated with each identified transition zone. If air infiltration is occurring, a thermal image may occur on the interior surface of the building envelope. Though this does not quantify the *amount* of leakage, it can confirm existing leakage pathways.
10. Interpret the pressures identified in transition zones.

### **16.3.4. Quantify Leakage Between Conditioned Areas and Attached Zones**

There are transition zones that have an access (for example, a garage or attic) and there are those that do not have an access (for example, porch roof systems). Calculating the amount of airflow in these two differently configured zones is accomplished in two different ways.

For zones with an access, the “Add a Hole” method of calculation can be used. For zones without entry, an alternative estimation of the hole size between the zone and the outdoors will need to be performed. Both methods are described below.

1. The “Add a Hole” Method

- As the living area is depressurized to 50 Pascal negative (with reference to the outdoors), measure the pressure in the zone with reference to outdoors.
  - If the pressure boundary between the living space and the zone is effective, the negative pressure of the zone will be 0 Pascal with reference to outdoors.
  - If the pressure boundary between the living space and the zone is not effective, the zone will likely be under some negative pressure. If the negative pressure does not exceed 20 Pascal, open the doorway, or entry hatch until the pressure in the zone doubles. Be sure to maintain the 50 Pascal negative pressure on the living space during this time. The hole that has been added to the zone reflects the effective size of the hole that originally existed to create the original negative pressure.
- Determine the leakage rate from the zone by subtracting the original fan flow from the flow with the hole opened. The difference identifies the leakage from the hole.
- If the flow is minimal and cannot be accurately measured with the blower door, measure the square inches of opening created by the hole, and the pressure difference across the hole. Apply this formula:  $\sqrt{\Delta P} \times \text{sq. inches of opening} \times 1.07 = \text{cfm}$ . If the zone is -14 Pascal and the house is -50 Pascal, then the pressure difference is 36 Pascal. If the pressure difference is 36 and the square inches of the opening is 150, then the hole leaks at  $6 \times 150 \times 1.07 = 963$  cfm. This would be the leakage of the zone to the house when the blower door was creating -50 Pascal in the living space.
- Determine the natural leakage rate of the zone by dividing the leakage rate of the zone by the LBNL or n factor for the building. (see blower door operating instructions)

## 2. The Alternative Method

- As the living space is depressurized to -50 Pascal, measure the pressure created in the transition zone.
- Identify the aggregate size of the hole between the zone and the outdoors. This is done by visually inspecting the zone and calculating the collective opening in square inches. For example: A 20' long fascia with a ¼" opening the entire length would equal 60 in<sup>2</sup> of opening.
- Apply this formula:  $\sqrt{\Delta P} \times \text{square inches of opening} \times 1.07 = \text{cfm}$ . If the pressure difference between the zone and the outdoors is 14 Pascal and the estimated opening is 60 in<sup>2</sup>, then the hole leaks at  $3.7 \times 60 \times 1.07 = 238$  cfm. This would be the leakage of the zone to the house when the blower door was creating -50 Pascal within the living space.
- Determine the natural leakage rate of the zone by dividing the leakage rate of the zone by the LBNL or n factor for the building.

### **16.3.5. Establish a Selected Pressure Difference Across the Air/Thermal Boundary**

An advantage to using the blower door in diagnostics is the ability to use varying pressures for various purposes. Additionally, the direction of airflow can be enforced to assist in the diagnostics.

1. Quantitative testing of air leakage is done at the industry standard of 50 Pascal, if possible. It is also helpful to use this higher pressure when verifying leakage through a transition zone, where the original 50 Pascal pressure within a living space may be reduced as it moves through zones with restricted airflow.
2. Locating leakage paths with the help of diagnostic smoke can often be better performed by using pressures in the range of 5-10 Pascal. At this pressure the smoke moves more slowly and in a stream from the higher to lower pressures. This can be more visually revealing, and can more precisely reveal leakage.

## 17.0 Inspection and Diagnosis—Duct Leakage

### 17.1. Scope

Comprehensive inspection and repair of leaking ductwork is vital for home performance. Air leakage from forced air distribution system - whether related to heating or air conditioning - creates inefficiencies that are direct (and easy to measure) as well as indirect. Duct leakage reduces the efficiency of the heating/cooling appliance, but can also create comfort and air quality problems for the occupants—along with imbalanced building pressures that augment the natural air leakage rates of the building. All these problems become more severe when ductwork is located outside of the conditioned space, such as in an attic or crawlspace. Visual inspection is an important part of the inspection process, but will not identify many of the most important leaks that are hidden by the building frame, insulation, or located in inaccessible areas. A duct blaster test is required to accurately assess leakage.

Many newer homes have duct leakage that equals 30% or more of the distribution system's capacity. Knowing this, we can only imagine the potential leakage in older buildings, where design and maintenance have not been high priorities.

### 17.2. Tools and Materials

Two Digital manometers, duct blaster, blower door, diagnostic smoke generator and infrared imagery equipment, duct mask, tape or plastic wrap

### 17.3. Procedure

#### 17.3.1. *Inspect Ducts and Associated Areas*

Inspecting ductwork involves identifying openings of various sizes in both the supply side and the return side. If ducts are outside of the conditioned area, these leaks will require sealing - or they can cause severe pressure imbalances within the building. For example, if return ducts are leaking hot attic air into the system, then cooling loads for the building will be dramatically increased. Hot attic air will be drawn into the system, as well as pollutants, i.e. dust, insects and insulation. Filters will be prematurely clogged, appliance efficiencies will be reduced, and the living space will be pressurized to cause additional air leakage. If supply ducts are leaking into the attic, conditioned air is being directed to the attic, rather than to the house - and the living space experiences a negative pressure which also causes additional air leakage.

1. Where ductwork exists outside of the conditioned area of the building, it should be inspected for insulation - and for sound principles of duct design. Many distribution systems have a noticeable lack of return air capacity and improperly sized or restricted ductwork.
2. Starting at the appliance cabinet, inspect the supply and return plenums for obvious leaks. Filter slots and their covers, as well as plenum connections to the appliance

cabinet, and takeoffs from the plenums are under the greatest pressures and will leak at greater flow rates than comparably sized leaks elsewhere.

3. Open the fan cabinet to inspect the seal around the return plenum and identify openings that may be provided in the cabinet (knockouts for optional return configurations).
4. Identify any intentional supply and return registers in the combustion appliance zone and determine if they are appropriate. Check to be sure that return openings in the combustion zone don't conflict with the venting of natural draft appliances.
5. Identify the collective *size* of the return and supply ducts. The return should closely match the supply with regard to the capacity of air it can handle. You should only be using 1/3 of the total static available on the return duct system—so the return ducts will require a larger area.
6. Inspect for restriction of airflow caused by poor duct design. Common design limitations to look for include small diameter ducts that are responsible for moving air over long distances, and also abrupt turns in ductwork.
7. Determine the range of air temperatures that the duct zone will experience, and propose duct insulation for uninsulated ducts located in unconditioned zones. Insulation should have a minimum R-5 rating of R-8 to R-11 depending on climate and system location.
8. Inspect all duct connections for proper fasteners and sealing for duct mastic inside the joint and a draw-band on the outside.
9. Remove duct register covers and inspect the transition (boots) to the living space. Often, the leakage between the duct and the surface of the living space is a major air leakage site. NOTE: High efficiency filters can't be used on most systems.

### **17.3.2. Establish Ducts and Zones in a Testing Mode**

Quantitative testing of duct leakage can identify the total leakage from the entire distribution system, as well as leakage in zones that are outside of the conditioned area of the building.

1. Test for total duct leakage
  - The duct zone should be relieved of any potential pressures by opening it up to the outdoors. This can be done by opening a window, door or in the case of an attic, the vent opening (attic ventilators) or the access to the living space, which will dissipate any pressures if a windows or doors of the house are open. The point is to create as close to zero pressure around the duct, so that leaks can be measured at a specific pressure of 25 Pascal.
  - All ducts are to be closed and sealed at the register with duct mask, tape or plastic wrap. It is important to make sure that ALL supply and return registers are sealed. Otherwise there is no accuracy to the test. Seal any register grills that may be in the plenums of the appliance. Make a final pass around the building prior to conducting the test, and look for any registers that may have been missed.
2. Test for duct leakage to the outdoors

- The duct zone that is located in the conditioned area of the building should remain closed.
- Duct zones that are outside of the conditioned area of the building can be left in their normal use configuration. Attic hatches should be closed and attic vents should remain in their operational configuration
- All ducts are to be closed and sealed at the register with duct mask, tape or plastic wrap. It is important to make sure that ALL supply and return registers are sealed. Seal any registers that may be in the plenums of the appliance. Look for registers that may have been missed.
- Configure the building and install diagnostic equipment for duct leakage testing.
  - For testing to be valid, you must set up a repeatable testing scenario.
- Disable all vented combustion appliances and air conditioners.
- Install the blower door in a doorway of the living space to outdoors. Leave the fan head sealed for the testing of the total duct leakage. The blower door will be used when measuring the duct leakage to the outdoors.
- Establish manometers to measure house pressure with reference to (WRT) outdoors, and fan pressure WRT the house.
- Install the duct testing equipment (Duct blaster) to the fan cabinet of the forced air appliance. If the cabinet is in a hard to access location, the duct blaster can be installed to a large, centrally located return air register. The register should be free of the duct sealing material, and the register grill can be removed altogether if it appears to be restrictive to airflow.
- Drill a 3/16"-hole into the main supply plenum, or in the supply trunk. Install a static pressure probe in this location (or put in the closest register) to measure airflow moving from the direction of the cabinet. This probe should remain undisturbed throughout this entire test.
- Establish a manometer to measure the supply plenum WRT duct zone and establish a second manometer also to measure the fan pressure of the duct blaster WRT duct zone.
- Open the duct zone to the outdoors, via windows, doors, etc.

### **17.3.3.      *Perform and Interpret a Cumulative Leakage Test***

The cumulative leakage test represents the effective leakage rate of all the holes in the ductwork added together. These leaks are a combination from both supply and return sides of the distribution system, and from all conditioned and unconditioned zones of the building.

1. Activate the duct blaster and slowly pressurize the ductwork until the manometer measuring duct pressure indicates 25 Pascal pressure.
2. As the duct is pressurized to 25 Pascal, read the pressure of the calibrated duct blaster fan and interpret (with a reference chart or programmed manometer) the amount of air required to maintain 25 Pascal of pressure in the ductwork. This reflects the total

cumulative leakage rate. 6% is an acceptable target for total leakage—so if the systems handles 1600 cfm, 6% is equal to 96 cfm.

#### **17.3.4. Perform and Interpret Duct Leakage to the Outdoors Test**

1. Leave the ducts, duct blaster and manometers in the same configuration established for the total leakage test.
2. If the duct blaster is located in a zone outside of the conditioned zone, then the tape on a single return register (closest return to the fan cabinet if possible) should be removed for the purpose of allowing the blower door to pressurize the ductwork. If the duct blaster is located in a zone that will be pressurized by the blower door, this step is not necessary since the open duct blaster fan orifice will provide the means by which the ductwork becomes pressurized.
3. With the blower door, pressurize the conditioned area of the house to 25 Pascal (positive pressure). This places 25 Pascal of pressure on any duct leak that is located in the conditioned area. This also places little or no pressure against the duct leaks located outside of the living space.
4. Inspect the manometer measuring the pressure of the duct supply plenum WRT the conditioned space. If there is no pressure difference indicated, then the ductwork is maintaining the 25 Pascal of pressure and is not leaking. If the manometer indicates a duct pressure that is a negative number, then pressure in the ductwork is being lost through leakage somewhere outside of the conditioned area.
5. Activate the duct blaster and slowly add pressure to the ductwork until the manometer measuring supply plenum pressure reads 0. This indicates that enough air has been introduced into the duct system to compensate for existing leaks.
6. Measure the pressure of the duct blaster fan and convert the pressure to airflow with use of a conversion chart or manometer calibrated to the fan flow. This is the quantitative duct leakage to the outside of the conditioned zone. 6% is an acceptable target for total leakage.

#### **17.3.5. Perform and Interpret Individual Duct Leakage Tests**

The test to locate duct leakage to the outdoors is referred to as a *pressure pan* test, but this can be easily accomplished following the quantitative leakage testing because the ductwork is already configured.

1. Remove the duct blaster from the appliance fan cabinet and close the cabinet access door. At the same time, remove the static pressure probe that has been positioned in the supply plenum, or it may be forgotten and left on the job site.
2. Any conditioned duct zone should be opened to the main living space of the building. Any unconditioned duct zone (i.e., crawlspace or attic) should be closed to the main living space.

3. Leave a single return air register (closest to the appliance) open to the living space. This will be the means of providing pressure to the entire duct system. The remainder of the supply and return registers should remain sealed.
4. Operate the blower door and depressurize the main living space of the building to negative 50 Pascal.
5. Using a manometer that has been configured to measure duct WRT living space, place the manometer hose through the tape of each supply and return register and identify the pressure difference across the register seal. If the manometer indicates zero pressure difference, then the ductwork associated with that register is not leaking. Increases in the pressure difference indicates increases in the leakage of the associated duct system.
6. Using a diagram of the floor plan of the building, record the results of pressure testing across the supply and return registers. This is referred to as “pressure mapping” the ductwork.
7. If outdoor leakage testing indicates substantial duct leakage, look for it in the vicinity of the ducts that are recording the greatest pressure difference (WRT) in the living space.
8. Remove the register seals from each supply and return register and re-establish the controls of the combustion appliances.

### **17.3.6. Identify Air Leakage Sites in a Forced Air System**

Not all the leaks of a forced air system are duct leaks. Some may be related to the plenums, fan cabinets, mountings for humidifiers, etc. Many of the distribution system leaks are easily identified through visual inspection, but it is likely that many leaks are not visible. With the use of pressures, diagnostic smoke and infrared, hidden leaks are easily detected.

1. Disable any vented combustion appliance or air conditioner, so they do not operate during diagnostic testing.
2. To the extent possible, close all duct zones and appliance zones to the main living space.
3. Install a blower door in a doorway of the living space to outdoors and configure a manometer to measure house pressure WRT outdoors.
4. Inspect all supply and return registers to assure they are in the open position.
5. Operate the blower door and depressurize the living space to negative 50 Pascal.
6. Position yourself in the closed duct zone with diagnostic smoke and puff smoke around all the components of the distribution system. The blower door is creating a negative pressure that is drawing air from the duct zone into the ductwork. The diagnostic smoke will reveal areas experiencing this negative pressure. It is important to use the smoke around areas where 100% visual inspection is not possible. Start with the fan cabinet, being sure to investigate all sides and the bottom of the fan cabinet - and move in the direction of the living space.
7. When inspecting flex duct, the primary leakage areas are at the end connections. When inspecting metal ducts, any seam and connect is a potential leakage site.

8. When inspecting return air systems that use the building frame as the duct, inspect for blocking that would prevent the negative pressure of the return from extending to the building exterior (i.e., enclosed floor joist system). When return ducts are part of the frame, a slight positive pressure and diagnostic smoke will indicate leakage in the direction of the problem.

**Table 17.1 Lighting (frequently used fixtures)**

Room	Fixture Type	Hours on per week	Wattage	Recommendation

**Table 17.2 Exhaust fan duct condition**

Exhaust Fan Location	Estimated Length of Duct	Condition

**Table 17.3 Exhaust fan flow**

Exhaust System Location	Estimated cfm

**Table 17.4 Appliances (primary)**

Location	Type	Recommendation

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**Table 17.5 Domestic hot water**

Shower Flow Rate	
Tank Temperature	



## 18.0 Inspection and Diagnosis—Cooling System

### 18.1. Scope

Specifying the correct air conditioning system for a home is an exacting science. Consider these performance specifications before you make system recommendations to your clients.

NOTE: You may need an EPA Refrigerant licensed technician to perform some of these steps.

### 18.2. Tools and Materials

TBD

### 18.3. Procedure

Diagnostic Tips: Start with a plan and be sure you can follow through on the installation. Make sure your customers understand and sign off on your plan. Make sure they understand the expected results and any known uncertainties. Provide installation instructions and standards for each measure. Installations should also always be accomplished in accordance with the manufacturer's installation instructions, industry standards, and local building codes. For long-term business reasons, you'll want to establish your own standards and stick to them. For example, when installing a straight run of pipe for make-up air, consider putting an "S" shaped trap into the system to reduce the possibility of backdrafts. Another option might be to use a power-assisted ventilation system if the zone is not balanced without punching a hole in the wall.

Use materials in accordance with industry standards and building codes. This is important for the industry as well as for your individual business and the repeat customers that you want to attract.

Make-up air requirements for the combustion appliance zone are defined by a NFPA (National Fire Protection Association) code. Installations should also always be done in a manner that assures air tightness of the installation, while protecting yourself, the home, and the occupants from the potential of harmful exposure through paint and dusts or changes in building pressure that may cause problems after you are gone.

#### 18.3.1. ***Balance Zonal Pressures that Exceed Action Levels***

1. Measure air pressures in all zones. The action level for conditioned zones is 3 Pascal. For unconditioned zones, this action level is relative to the amount of air leakage to the outside. Set the zone up in such a way as to test the cfm flow across the pressure boundary.
2. In a conditioned zone, air pressure is a function of the amount of leakage to the outside. If an attic is very tight, it doesn't take much to affect the air pressure. For example, if a house creates 4 Pascal of pressure in the attic when an air handler comes on, this might seem high. But if the attic has substantial air leakage, then it would take quite a bit of air to bring the pressure difference to 4 Pascal.
3. To deal with balance zonal pressures that exceed action levels:

- Add a vent to a nearby wall.
  - Change the venting to power-assisted.
  - A barometric damper will allow the vent to open and close whenever necessary.
4. In unconditioned space—with the exception of the combustion appliance zone—the pressure balancing strategy would be to air seal the leaks between the conditioned and the unconditioned space.
  5. Where atmospheric appliances are in use, the pressure balancing strategy would be to provide enough air that even under a worst-case scenario the appliance meets venting standards and doesn't back-draft or produce carbon monoxide. This is possible by providing a make-up air vent from the outside. To determine how much make-up air is necessary, try opening a window and measuring the difference.

### **18.3.2. Ascertain Duct Leakage**

See the Duct Blaster Operation Protocol.

The average forced air distribution system in California leaks about 30%, or 200 to 500 cfm. Sealing a system down to a 5% leakage rate (a 25% system leakage reduction) will reduce system energy consumption by about 19%.

*All air distribution systems should be sealed below 60 cfm25, or 5% of fan flow, whichever is less.*

### **18.3.3. Consider Duct Conduction**

The conductive heat transfer through the duct insulation can be very large at design conditions. Calculate the conductive heat transfer by using the formula  $Q=U*A*\Delta T=(A*\Delta T)/R$

The duct surface area A (in square feet) can generally be estimated to be about 40% of the conditioned floor area. The estimated conductive duct heat gain Q (in Btu/hr) at design conditions for a 2,000 ft<sup>2</sup> house in the Central Valley with R-4.2 ducts in the attic can be calculated as follows;  $(2,000 \text{ ft}^2 * 40% * (140^\circ\text{F attic temperature} - 60^\circ\text{F supply temperature})) / 4.2 = 15,200 \text{ Btu/hour}$  (1.3 tons of capacity at the standard 12,000 Btu/ton).

To reduce this loss effectively, duct insulation should be R-8.0 or greater. Duct system surface area should be minimized by shortening ducts whenever possible. Running supply ducts to the closest corner of each room and minimizing the number of supply registers should always be a primary home assessment and retrofit design focus.

### **18.3.4. Consider Room-to-Room Air Flows**

Room-to-room supply airflows, on average, are 40% low to large rooms and 300% high to small rooms such as bathrooms and laundry rooms. Since thermostats are typically located in large rooms, systems must run longer than necessary to satisfy the thermostat while bathrooms and utility rooms are over-cooled.

*Room heating and cooling loads must be determined by using ACCA Manual J (or comparable) methodology. Manual J inputs must use target (improved) air infiltration and duct leakage rates.*

Room airflows must be adjusted to within 10% of the heating and cooling loads for the room. Manual balancing dampers must be installed on each branch duct so supply air volumes can be adjusted without creating noise or affecting supply grille throw direction.

1. Non-diffusing grilles must be used to provide maximum throw distances.
2. Grilles should not have dampers since they increase supply noise and can reduce airflow across the evaporator coil if closed.
3. Supply grilles must be sized to provide delivery velocities between 500 FPM and 700 FPM. If the delivery velocities are too low temperature stratifications will occur. If the delivery velocities are too high there may be too much noise at the grille.
4. Eliminate drafts on occupants by only supplying air to the unoccupied portion of the room (above 6' and within 12" of the walls). Air velocities in the occupied portion of the room must always be less than 25 FPM.

### **18.3.5. Consider Air Flow through the Evaporator**

Coil: Most equipment manufacturers require a nominal airflow of 400 cfm/ton through the evaporator coil. The average California duct system only has 335 cfm/ton of airflow, thereby reducing system efficiency and capacity by about 10%. If the airflow is below 350 cfm/ton the system refrigerant charge cannot be accurately adjusted. In dry climates, such as most of California, evaporator airflows greater than 400 cfm/ton should be achieved to provide more sensible cooling and higher efficiency.

Evaporator airflow constantly declines over the life of the system due to coil fouling, dust buildup on fan blades, and dirty filters.

1. *Design evaporator airflow rates must be between 440 cfm/ton and 480 cfm/ton (110% to 120% of nominal air flow).* If the distribution system employs motorized dampers for zone control, 400 cfm/ton evaporator airflow must be maintained at all damper configurations.
2. Bypass ducts cannot be used to maintain evaporator coil airflow since the bypass duct will lower the entering air temperature to the coil.
3. High efficiency filtration should never be used unless the system is designed to accommodate the added static friction that high efficiency filters create. Filter grilles must be sized to 2 ft<sup>2</sup> per ton (or about 15" x 20" per ton, or equivalent). Maintain filter velocities below 300 FPM for the active area of the filter and a static pressure below 0.10" water column.

### **18.3.6. Consider Refrigerant Charge**

Research shows that the refrigerant charge in 70% of air conditioners needs to be adjusted. Inadequate adjustment of refrigerant charge affects both the capacity and performance of an air conditioner by as much as 20%. Refrigerant charge not adjusted for non-standard line-set lengths and leaks are the two most common causes of incorrect refrigerant charge.

1. New or replacement systems should have a properly installed thermostatic expansion valve (TXV). A system with a TXV provides better performance as indoor and outdoor temperatures can vary with refrigerant charges that are not correct.
2. Check adequacy of refrigerant charge. New or replacement systems must be evacuated to 300 microns and held below 500 microns for 5 minutes.
3. Properly adjust refrigerant charge using the standard Subcooling method. This is often done at the diagnostic stage if refrigerant charge is being checked at that time.
4. Check that the refrigerant line set is sized to provide full capacity and efficiency. As line-set lengths increase, the diameter of the vapor line must be increased a size or two to maintain capacity and efficiency. Use standard references.
5. Check that the evaporator coil and condensing unit are properly matched to provide rated efficiency and capacity. This often requires a coil that is as much as a ton larger than the compressor size. Coils must be sized for design airflow to avoid condensate blow-off.
6. Assure that the line-set has R-3.0 insulation or greater.

### **18.3.7. Consider Condensing Unit Sizing**

Condensing unit oversizing reduces the system efficiency, reduces the system's ability to remove moisture from the home, and reduces comfort. Systems are sometimes oversized 100% or even more. Average amounts of oversizing increase system operating costs 10% or more.

When air conditioner replacement is being considered, the system should be sized in accordance with the home's thermal load as calculated using the ACCA Manual J/Edition 8 method or equivalent.

## **19.0 Inspection and Diagnosis—Heating and Cooling Ductwork Design and Airflow**

### **19.1. Scope**

Heating and cooling ductwork should be designed to deliver the necessary volume of air required to each conditioned area of the building, as determined by a heating/cooling loads calculation. In addition, there are minimum amounts of air that must move through the heating/cooling appliance to assure efficiencies are maintained, and the integrity of the appliance components not compromised. If airflow across the heat exchanger is too low, the appliance will short cycle, approach high limit shut-off and potentially damage the heat exchanger. Air conditioning systems also require an established amount of air moving across the evaporator coil to maintain efficiency. Low air flow across and evaporator coil in the cooling mode may cause the coil to ice. There are several design issues that determine how much air moves across the heat exchanger/evaporator coil, including duct design and sizing, balancing of supply and return, fan characteristics and maintenance of filters and coils.

### **19.2. Tools and Materials**

TBD

### **19.3. Procedure**

#### **19.3.1. *Identify the Components of the Distribution System and Provide a Visual Inspection***

A forced air distribution system moves supply air across a heat exchanger/cooling coil by means of a fan. As air passes through the appliance, it is conditioned and delivered to the house through the supply ducts. At the same time, return air from the house is delivered back to the appliance for conditioning by the return air ducts. This convective loop should proceed with a minimum of resistance to flow and at velocities that compliment industry standards and the occupant's comfort.

1. The heat exchanger and cooling coil are located in the appliance cabinet, between the fan and the supply plenum. They provide the conditioning medium for the air and provide a fair amount of restriction to airflow. This aids in the energy transfer from appliance to air, but too much restriction can result when maintenance and service are not provided. Heat exchangers and cooling coils are not always easy to inspect if encased in the appliance cabinet.
2. Inspect for soot, rust, and scale in the combustion chamber and vent system. Signs of these may indicate the heat exchanger is dirty and restricted. AC evaporator coils may be accessible for inspection through a service panel. Dust and debris on the coil can severely restrict airflow for heating and cooling. Secondary heat exchangers in condensing furnaces may also collect debris and should be inspected.
3. The supply plenum is located directly over the heat exchanger/cooling coil and serves as the distribution center for ducts carrying conditioned air to the zones of the building.

The return plenum serves as the central collection area for air returned from the building for conditioning. Properly designed plenums distribute an even pressure to ductwork that assures each duct moves a portion of the distribution air. Inspect the plenum connects to the appliance for a tight seal. Inspect all plenum to duct transitions for a tight seal.

4. Most distribution systems are equipped with a filtering system designed to remove dust and debris from the air. Filters are usually located on the return side of the distribution, either at a central register grill in the living space or near the distribution fan. It is critical to the performance of the appliance that the filters remain clean and pose as little restriction to flow as possible.
5. Ductwork transports air to and from the conditioned space. It may be made of sheet metal, pre-manufactured metal stock, duct board, or flexible coils of plastic lined material. It is also common for return ducts in multi-story buildings to be made from the building frame, i.e. floor joist or wall stud system. These tend to be problematic when not air sealed at installation, as leakage sites may be difficult to access.
6. Normally ductwork connects to a ceiling, floor or wall pan, a metal box behind the register that transitions the duct to the living space. The registers keep large things from falling or crawling into the ductwork and may also aid in distributing the conditioned air to the room by dampers and vanes.
7. Balancing dampers located in each supply branch duct and near the main trunk, further control the volume of air transferred to individual registers. The settings for these dampers are dependent on the design of the ductwork and occupant comfort requirements.

### **19.3.2. Evaluate the Heat Transfer Characteristics of the Heating/Cooling Distribution, With Occupant Comfort in Mind**

The occupants may be able to offer insights into the performance of the distribution system—with comments about seasonal comfort issues. Failure of a distribution system to adequately condition the living space may be corrected by simple adjustments and balancing or may be the result of poor duct design, excessive heat transfer through the shell, appliance size or system maintenance.

Questions recommended to be asked of the occupants:

- Does the building heat/cool uniformly?
- Are there areas or times of discomfort with the heating/cooling?
- How often is the appliance serviced and filters changed?
- Are there ever any seasonal adjustments made to registers or dampers?

### **19.3.3. Identify the Basic Principles of Proper Duct Design**

Duct design is an important aspect of distribution delivery. There are several characteristics of a duct system that should be evaluated in context of comfort and efficiency.

1. Duct design is based upon external static pressure. This is the resistance of all components outside of the appliance cabinet. If an evaporator coil is part of the conditioning system, that component is part of the duct system resistance.
2. Ductwork for the return side of the distribution system should be closely balanced in air handling capacity to the supply duct. 100% of the air supplied to the conditioned space must be returned to the appliance through the return duct work. All too often, the return side lacks the design to move the proper quantity of air from the living space or zones of particular zones of the living space. There is no risk of providing too much return air to the appliance but too little return can damage heat exchangers, cause cooling coils to freeze up, adversely affect the appliance efficiency and provide comfort problems. Testing the air flow volume and temperatures across the heat exchanger/cooling coil are the best ways to identify inadequate supply and/or return air capacity.
3. Ductwork, whether supply or return should be designed as straight and unrestricted as possible. Hard turns in ductwork should be avoided, to the extent possible, and the length of ducts, to their location in the conditioned space, should be as short as possible. If ductwork is suspended, it should be supported every 4–6', without sagging.
4. Ducts should be constructed of material that is smooth on the interior and poses the least amount of restriction to flow. This is especially true for ducts that transport air long distances.
5. As a rule of thumb, total external static pressure of a heating system is designed to .2"W.C. static pressure. A cooling duct system is designed for .5"W.C. external static pressure.
6. In residential applications, main supply trunk velocities should be in the range of 700–900 FPM. Branch supply distribution ducts should be designed for 500–700 FPM.
7. Ducts should be constructed of material with an aspect ratio as close to 1:1 as possible. This refers to the relationship of the duct width and height. A 6" round duct has a 1:1 ratio, as does a 6 in<sup>2</sup> duct. A duct that is 12" wide and only 4" in height has a 3:1 ratio and should be avoided if possible.
8. Velocity of air flowing through the return duct system should be slightly reduced as compared to the supply velocity to limit noise from airflow.
9. Ducts should be secured with fasteners and sealed with mastic at each connection, from the plenum to the register boot.
10. Zones that are provided supply air must have a means of providing return air to the appliance. This can be done directly with return ducts from the zone or indirectly by having openings to other zones that are equipped with return ducts. If return is not provided, pressures will result in the zone and proper convective cycling will be interrupted.

11. Bathroom and Kitchen zones will not normally have return air ducting to those rooms to eliminate the potential of introducing odors and excess humidity to the balance of the dwelling.

#### **19.3.4. Measure Airflow Across the Cooling Coil**

Cooling appliances are rated by the manufacturer in terms of Btu capacity, with reference to proper design. One ton of cooling is equal to 12,000 Btu of potential cooling if the proper airflow of 400 cfm is provided. Many homes have equipment oversized for the cooling load of the building, but because of duct leakage or improper airflow, the performance of the appliance is not satisfactory. Several methods exist for determining the amount of air that moves across the cooling coil. Select the one most appropriate for your situation.

1. *The temperature rise test* measures the temperature difference between the supply and return air in the plenums and can be used to approximate when the air flow is in the correct range.
  - Drill a 3/16"-hole in the supply trunk duct out of line of site of the heat exchanger and return plenum. Using a digital thermometer or pyrometer, insert a thermistor into each test hole drilled.
  - Activate the cooling appliance and allow it to operate for 10 to 15 minutes.
  - Measure the difference between the supply and return air temperature. The general range should be 18–20°F temperature readings outside this range could result from improper airflow.
2. The duct blaster testing method uses the duct blaster to measure effective air flow. This is a logical sequence to appliance testing where duct leakage testing is being performed.
  - Inspect all supply and return registers and make sure associated dampers are in the open position and all registers are unobstructed. Open any restricted balancing dampers as well.
  - Inspect any air filters and make sure they are clean. Remove the air filters if they are noticeably restricted with dirt.
  - Place a 3/16"-hole in the supply plenum or in the main supply trunk, very near the supply plenum. Install a static pressure probe connected to a manometer to measure supply plenum WRT appliance zone.
  - Operate the air handler of the cooling appliance and note the positive pressure level created in the supply plenum/trunk.
  - Turn off the duct blaster and remove it from the fan cabinet. Leave the static pressure probe and manometer connected to the supply plenum.
  - Close off the return plenum by taping cardboard across the opening of the plenum connect to the fan cabinet. Re-install the duct blaster to the fan cabinet. This procedure has made the duct blaster fan the only source of return air to the fan cabinet. In this configuration, all system air can be measured through the

duct blaster fan. Connect a second manometer to measure duct blaster fan pressure WRT the duct zone.

- Activate the air handler and note the pressure created in the supply plenum. If it is less than the original plenum pressure recorded at the very beginning of this test, then activate the duct blaster, adding air to the fan cabinet until the supply plenum pressure is identical to the original pressure.
  - Read the pressure of the duct blaster fan and interpret the airflow (cfm) through the fan by a conversion chart or calibrated manometer. This represents the original airflow required to achieve the original supply plenum pressure.
3. *Flow plate testing* uses a flow plate; a calibrated device that is installed in the vicinity of the fan cabinet to measure the effective flow of air across the cooling coil. As with any specialized diagnostic equipment, it is important to read the operators manual and to have a copy on-site for reference.
- Inspect the air filters and make sure they are clean and unrestrictive to air flow.
  - Install a static pressure probe in the supply plenum or the supply trunk near the plenum. Connect the pressure probe to a manometer to measure the plenum pressure WRT the appliance zone.
  - Connect the flow plate to a manometer measuring the flow plate pressure WRT the appliance zone.
  - Operate the appliance under normal operating conditions and record the pressure of the supply plenum. Turn off the appliance, but leave the pressure probe and the manometer in place.
  - Install the flow meter in the filter slot or in the opening between the return plenum and the fan cabinet. It is important that it be installed with the front of the flow plate facing the flow of air and that it be properly sealed so all air passes through the plate rather than around the plate. Seal the filter slot with tape, to avoid air leakage around the flow plate.
  - Operate the system again and measure the operating pressure of the supply plenum.
  - Determine the resistance correction factor based on the difference between the original operating pressure in the plenum and the plenum pressure with flow plate installed.
  - Calculate the fan flow from the pressure created across the flow plate and multiply it by the correction factor determined in the step above. The result is an estimation of the original flow across the cooling coil.
4. *Flow hood testing* involves a flow hood. This allows for the testing of airflow from individual registers. The device is tightly positioned over a register, as sensors measure the flow pressure and convert it to cfm. This method of airflow measurement has the advantage of being able to approximate the energy transfer of individual ducts.

Positioning the flow hood over registers that are incorporated in cabinets, or located tight to the wall can be problematic.

- Identify all supply registers. Operate the air handler and position flow hood over the register. Measure the flow pressure and convert to cfm of airflow.
- Add the cumulative total of all duct flow to quantify the total airflow across the cooling coil or heat exchanger. Compare these results to the design criteria originating from the Manual J load and Manual D calculations.
- Compare the energy transfer to each room or zone of the building with the requirements Calculated by Manual J.

### **19.3.5. Evaluate Air Flow Volumes With Relation to Recommendations**

The volume of air (cfm) delivered through a distribution system is based upon the manufacturer's recommendations for the appliance. There are many factors, including the firing rate of heating systems and the Btu capacity of air conditioners that determine the recommended airflow.

#### 1. Heating appliances

- Manufacturer's recommendations for airflow are based on this formula:

$$cfm = \text{Btu per hour of output} / \text{temperature rise across the heat exchanger} \times 1.08$$

For example: a 50, 000 Btu output appliance/60°F temperature rise  $\times 1.08 = 900$  cfm.

- Airflow should be sufficient that the temperature rise is within manufacturer specifications. The heat transfer process is more efficient if the heat exchanger gives off heat at the same rate it collects heat. Approaching high limit usually translates into very inefficient short cycling and potential stress damage to the heat exchanger. Measure the supply plenum temperatures at the point when the distribution fan begins to operate and determine if the temperature continues to rise through the cycle.
- Many appliances have multi speed fans that can be adjusted to operate at higher or lower fans speeds. Consider higher speeds when supply plenum temperatures increase above the high end of the manufacturer temperature rise or when long ductwork requires additional pressure. Belt driven blower assemblies may have an adjustable sheave to adjust air speed. Pulley size can be changed to affect airflow changes if necessary. A word of caution when increasing fan speed on a belt driven blower assembly, ensure that the maximum rated running current draw of the motor is not exceeded.
- High plenum pressures may create banging, noisy or whistling ducts, especially on the return air side. This could indicate a need for additional air, especially if supply air temperature increases above the manufacturer stated temperature rise. Adding more return air ducting and grills may reduce return plenum pressures and quiet ductwork.

## 2. Cooling appliances

- Manufacturer's recommendations for airflow are based on 400 cfm per ton (12,000 Btu/hour) of cooling capacity. A 3 ton air conditioner should have an airflow rate of 1200 cfm for optimal performance.
- Air flow across the evaporator coil should be sufficient to maintain an 18–20 degree temperature difference. Temperature not in that range could be caused by lack of airflow or poor refrigerant charge. Inspect the evaporator coil for dirt, bent fins or other obstructions to airflow.
- Cold air is more difficult to move than warm air, so it is usually recommended that variable speed fans be set on higher settings to handle more air at greater pressures.

### **19.3.6. Identify Factors Affecting Airflow Requirements**

When considering the airflow requirements for space conditioning, it is important to consider the total heat losses and gains for the building. This is accomplished through a Manual J calculation, which identifies total building Btu requirements and individual room or zone needs. From this load calculation, appliances can be selected and airflow requirements can be specified. The comfort requirements of the occupants should also be considered in the final determination of airflow requirements.

1. The conditioning appliance must have an output rating high enough to satisfy the building load requirements, and supply the losses realized by distribution inefficiencies. This usually means the appliance output must exceed building loads by 10-15%. These distribution inefficiencies are part of the Manual J calculations.
2. Energy is delivered by airflow to each building zone, in an amount equal to the loads experienced by the zone. Two rooms of the same size may have different loads based on the amount of windows, orientation, use, shading, and location within the building.
3. The customer is the final determinant in calculating distribution airflow requirements. Special needs may impact the building and zone temperature settings, which may be different from the Manual J calculation. The customer should be asked about their needs and typical temperature settings. The customer can also provide valuable information about their satisfaction with past performance.

### **19.3.7. Evaluate Cooling Load Reduction Options**

Air conditioners are costly to operate and every measure to reduce heat sources in the building should be considered. Just about every system improvement identified in the final proposal will likely have a direct impact on reducing cooling loads. Besides the general energy performance variables, there are often things that occupants can do to improve their comfort and efficiency that have more to do with building management and maintenance.

1. A comprehensive inspection of the thermal boundary, the air leakage issues, the ventilation strategy, equipment performance enhancements, etc. will determine the measures that will have the greatest impact on the heating and cooling loads of the building.
2. Instruct occupants in ways to use air circulation, with fans and the air handler, to provide a more comfortable environment in the times when air conditioning is only marginally required. Moving air is sensed as being cooler than static air of the same temperature.
3. Instruct the occupants on ventilation strategies to keep humidity levels within limits and to exhaust warmer air at the end of the day. Open windows on hot days is folly, but may be recommended between sunset and sunrise. After hours mechanical ventilation is also a sensible consideration.
4. Instruct occupants on the importance of using window drapes to control solar heat gains through glazing. This also lowers the interior radiant wall temperature and improves comfort.
5. Instruct occupants to the importance of keeping registers for supply and return unobstructed and open to the rooms.
6. Instruct customers as to the importance of servicing mechanical equipment. Provide a suggested maintenance schedule for guidance and referrals to home performance trained contractors, if needed.

### **19.3.8.      *Identify Distribution Components Requiring Insulation***

Insulating of the distribution system can be an important measure to improve distribution efficiency. Insulation in zones that are extreme in temperatures, (for example, an attic in the summertime), is critical to systems efficiency and higher R-values are recommended. 30% of the conditioning efficiency can easily be lost through long, un-insulated or under insulated ducts.

1. Supply and return plenums in unconditioned zones should be air sealed and well insulated to a minimum value of R-7.
2. Ductwork located in unconditioned zones should be air sealed and insulated to a minimum value or R-5.

## 20.0 Inspection and Diagnosis—Conditioned Zones

### 20.1. Scope

There can be pressure imbalances within the conditioned zones of any building. In certain situations, this can create a myriad of health problems. It can also have a negative impact on energy efficiency and general comfort.

With regards to zonal pressures, the living space should be kept as neutral as possible through the use of space conditioning equipment and forced air distribution. The issue becomes “how much air should go into a zone, compared to how much air leaves the zone by way of the distribution system?”

It is common to find conditioned zones that experience high pressures because they are supplied with conditioned air, but have no way to push air to the return side of the distribution system—or visa versa. Doorways that can be closed are frequently the cause, but the lack of—or isolation of—return air registers can also be the cause.

Distribution system leakage can also cause measurable imbalance within the living space. Where supply ducts leak outside of the conditioned area, the living space may realize a negative pressure, and return ducts leaking to the outside will cause a living space to have an overall positive pressure.

NOTE: Most HVAC contractors agree that the value of the Conditioned Zone Inspection is primarily *after* duct and building air sealing repairs have been made, and the initial inspection only serves to provide a benchmark. Whatever pressure exists in the building will likely change as a result of distribution repairs, air sealing and improved insulation of the building.

### 20.2. Tools and Materials

Digital manometer.

### 20.3. Procedure

#### 20.3.1. ***Identify and Configure Each Potential Zone of the Living Space***

1. In the context of this inspection, a zone refers to any space that is under the influence of the air handler and can be separated from any other space in the living area. For example, a bedroom can be separated from other bedrooms by interior doors. A second floor can be considered a zone if it can be separated from the primary return on the first floor. The potential possibilities are numerous. Once the different zone configurations have been identified, each should be pressure tested.
2. Configure the building into “winter worst case” mode” by closing all primary windows and doors. Close any exterior doors to garages, sun porches or attached unconditioned zones.
3. If you are prepared to rebalance the entire system, open balancing dampers on ductwork and dampers of registers and grills. All registers should be unobstructed and open to the zone.

4. Identify any rooms in the living space that do not have a supply or return air duct, and close the door between these areas and the main body of the house because the volume of that room will diminish pressures in the main body of the house.
5. Identify any rooms in the living space directly connected to the main body that have return-only ducts. Because negative pressure created in these zones will influence the pressure of the main body of the house, these rooms should be open to the main body of the house, if directly connected to the main body.
6. Locate the primary return air registers and close any doors to rooms (or building levels) attached to that zone. It is likely that some of the rooms or levels of the building will have at least a supply register, and maybe a return.

*At this point, the main body of the house contains the central or primary returns and has been segregated from individual rooms with interior doors.*

### **20.3.2. Test the Levels at Which Positive and Negative Pressures Occur Within Zones of the Building**

This test will measure the levels of pressure created within the living space, with the operation of the air handler. The main body of the house will be used as a reference for pressure inputs from surrounding zones or rooms off the living space. The acceptable level of pressure difference is +/- 3 Pascal, from the main living area. Pressures can be subtle enough to warrant the use of a digital manometer, with better resolution at low pressures.

1. Start up and operate the air handler in cooling mode with higher fan speed.
2. Measure the main body of the house with reference to outdoors. And record your results.
3. Operate the air handler by means of the fan switch on the thermostat—highest fan speed.
4. Once again, measure the pressure of the main body of the house in comparison to the outdoors. Differences indicate the predominant condition this zone is likely to operate in under normal operating conditions.
5. Set up a digital manometer to measure the pressure differential of each segregated zone, to the main body of the house.
6. Place the hose connected to the input port under the door to the segregated zones. In each case, measure and record the pressure.
7. While measuring the pressure in zones exceeding +/- 3 Pascal, gradually open the door until the room pressure falls to or below the 3 Pascal level. Approximate the square inches of opening required to pressure relieve the room and record.
8. Draw a footprint of the building and identify zones and pressures, or use a data collection table to plot zones, relevant pressures, and opening size for pressure balancing.

9. Where measured pressures exceed +/- 3 Pascal with reference to the main body of the house, pressure-balancing options should be considered.
10. Upon completion of the tests, turn off the air handler and re-establish the building to its normal operating state.
11. With the air handler off, operate the exhaust ventilator in each bathroom, or room containing an exhaust only appliance.
12. Close the door to that room and measure the pressure of that room with reference to the main living space. Exhaust appliances in small rooms may create a high negative pressure, which translates into reduced airflow through the mechanical ventilator. Pressure relief options should be considered when pressure in these zones exceeds -3 Pascal.

### **20.3.3.      *Develop a Pressure Balancing Strategy***

The balancing strategy should be as simple as possible. The goal is to create a connection between the segregated zone and the main body of the house to reduce pressure differentials greater than 2 Pascal. A good approximation of the required opening size is derived by measuring the door opening size as it is opened to find the size that's required to neutralize high pressures.

1. Balancing dampers in the ductwork should be positioned to best represent the conditioning needs of the zone. Complete a Manual D distribution analysis and measure the air going into the room to see if it meets the load requirements for Manual D.
2. Consider adding a return air duct to an area of the building that is not well represented with return, especially if it has been determined that the central system requires additional airflow. If you notice high negative pressures on the return side, or weak supply side pressures—or if there are noises created in the system—it may indicate return air starvation.
3. Consider adding a return air duct to areas where occupants complain of discomfort, or poor temperature control. Adding returns can boost the performance of existing supply ducts.
4. Consider undercutting doors to rooms exhibiting pressures in excess of +/- 2 Pascal. A 1" undercut translates to 32 in<sup>2</sup> of opening and is often the easiest, effective solution.
5. Consider balancing grills through the wall, positioned over door headers. An 8 x 14" grill may have a free area of 70 in<sup>2</sup>.
6. Consider installing a jumper duct from the room to the main living area. A 10" duct offers approximately 75" of opening.

### **20.3.4.      *Assess and Address Energy, Health, and Safety Implications Created by Zonal Pressures***

There are a number of actions that could be considered. For example:

1. Adding returns to a distribution system that is starved for return air dramatically improves the performance and life use of the appliance by keeping the cooling coils from frosting reducing temperatures between the heat exchanger and the cooling coil.
2. Reducing pressures created by distribution imbalances reduces the air leakage rates of the building under natural conditions. Pressures are the driving force behind air leakage, and these mechanical pressures can easily double the typical house pressures realized by stack effect.
3. Increasing supply air and improving the convective flow around the living space contributes to better air circulation and more moderate building surface temperatures. Air distribution systems often supply ducts on exterior walls and return air ducts towards the center of the space. This can help prevent drafts, remove household moisture and provide a more regulated space conditioning temperature.
4. Correcting zonal pressures can reduce air leakage from the garage or other potentially contaminated zones into the house, by reducing the causes of negative pressures within the home. This is not a substitute for good air sealing between the house and garage, but part of a comprehensive package of responses that work together.

**Table 20.1. Conditioned zones**

Procedure	Task	Component	Check-list	Score	Comments
Perform pressure test of conditioned zones within the living space	Identify all possible zones within conditioned living space	Identify main body of the house. Identify significant conditioned areas that can be isolated from the main body of the house.	_____ _____		
	Configure the building for testing	Building established in winter mode (primary windows and doors closed). All Passive ventilators with dampers closed. All mechanical ventilators/exhausting appliances operating. Segregate supply zones from return zones, to extent possible.	_____ _____ _____ _____		
	Initiate test	Activate air handler	_____		Main distrib. fan of primary heating/cooling

Procedure	Task	Component	Check-list	Score	Comments
					system.
	Conduct manometer tests	Establish manometer-tested zone with reference to outdoors or main body. Measure pressures of each zone, closed to main body of the building. Measure pressures of main body of building, segregated from all positive pressure zones, and open to all negative pressure zones.	_____ _____ _____		
	Record results	For each zone, record greatest positive pressure achieved. For each zone, record greatest negative pressure achieved. Relevant findings reported on building report.	_____ _____		

**Table 20.2. Pressure mapping**

Fan Condition	Reference Zone	Secondary Zone	Pressure Difference (Pa)	Significance
On				



## 21.0 Inspection and Diagnosis—Baseload Appliances and Lighting

### 21.1. Scope

The term “baseload” generally refers to any appliance that is NOT used for space conditioning. This means all load-bearing appliances—to include cooking, dishwashing, refrigeration, lighting, communication appliances and domestic water heating (if heated by electricity). It’s important to note that appliances that run compressors tend to use more energy as they age, whereas stereo equipment (for example) does not. The ultimate goal of this inspection is to identify opportunities for savings.

### 21.2. Tools and Materials

Clamp-on amp meter, watt-hour meter, light meter.

### 21.3. Procedure

#### 21.3.1. *Seek Information From Occupants Related to Baseload Appliance Usage and Performance*

Identify habits and “comfort issues.” This information will be very relevant to your analysis. Expect teen-age girls to use more electricity when nobody is around to measure it. Consider the following:

1. How much the appliances are used in terms of hours per day or per week? Amps x volts = watts. If the wattage is on the appliance, then this is just a math problem. Multiply the wattage x the usage hours per day X days per week X 52 = total kilowatt-hours (kWh) per year. If an appliance only runs intermittently, a watt-hour meter must be used for this equation.
2. What is the age of each appliance, and any inefficiencies that could contribute to additional energy usage?
3. What historical problems and servicing has been required (for example, a refrigerator that loses its freon gas periodically should signal that there’s a problem).
4. Note that all electrical equipment adds to internal heating gains, and in the summer these have to be dealt with by the air conditioner. Even a ceiling fan is a 100% efficient electric heater.
5. Look for appliances that have a “phantom load” whereby energy is being used even when the appliance is off. Newly purchased electronic equipment should be tested with a watt-hour meter in both ‘on’ and ‘off.’ This is true of any appliance that has a constant light built in—or any appliance with a digital clock.
6. Are most clothes washed in cold water? If not, this should be considered. Are dryer lint-traps cleaned before every use?

### **21.3.2. Conduct a Lighting Survey for Efficiency Considerations**

Re-lamping is one of the single greatest potential energy savings that can be employed with the least amount of effort. Overall, the lifestyle goals of the occupants should be considered first and foremost. The goal of the lighting survey is to identify the options that should be considered. You'll be able to develop a map of wattage and hours for the major energy-using appliances.

The standard equation to consider with each light bulb:

- watts x hours x days

Once you've got real numbers, you can compare and contrast different wattage bulbs, to quantify the potential for savings.

1. As part of the lighting survey, you should analyze the electric bills. When all the bills are spread out in front of you, you'll be able to extrapolate what percentage is used for heating and cooling (some months are heating months and some months are cooling months). If there is a huge spike in the winter, it may not *just* be that the days are shorter, it's probably an electric space heater to blame. You can expect winter lighting usage to increase approximately 20%. Be suspicious of any usage that exceeds a 20% increase, and look for any unusual patterns.
2. In any home, there will be a percentage of lights that can be transitioned from incandescent light to fluorescent lights without impact. A light meter can be helpful in illustrating the fact that while fluorescent may not seem quite as intense as an incandescent, it is still providing the same amount of lumens while using significantly less energy. Any incandescent lighting that is used more than 3 hours per day should be changed to fluorescent bulbs. Because fluorescent bulbs generate less heat than incandescent bulbs, re-lamping with fluorescent light bulbs also reduces the cooling loads on a building.
3. Using the occupants' parameters, determine where bright lights are needed (generally kitchen and bathroom) and where they are not really needed. Make a note of any lights that are used more than 4 hours per day. These should certainly be re-lamped. Dimmers, night-lights, and timer-based fixtures should be considered where appropriate.
  - For example, if you replace a 60-watt bulb with a 20-watt bulb, the savings is about 60%. You might not want to do this in the kitchen or the bathroom, but if done for the hall lights it could potentially add to comfort and cost savings. Return on investment could be within 6 months, and the new fluorescent bulbs come with a 10-year lifespan.
4. Because fluorescent bulbs generate less heat than incandescent bulbs, re-lamping with fluorescent light bulbs also reduces the cooling loads on a building.
5. The lighting survey should look to accentuate the benefits of available daylight. This means that window treatments should allow for both open and closed positions; open when the sun is shining, closed at night, or when the sun is not shining. Window

treatments should be closed on a sunny day when the AC is on and daylight is not as critical.

6. There may be options for additional window placements even in an existing building.
7. Think about how light comes into the building—or doesn't come into the building—due to shrubbery or trees. Winter lighting can be significantly improved by adding reflective surfaces when appropriate. This can double the intensity of available light by bouncing it around. For example, light-colored ceilings will improve luminary opportunities, as opposed to dark ceilings.
8. Lighting ballasts should also be considered for a 25% savings. Older fluorescent light bulbs trap light within the bulb itself, and have ballasts that use unnecessary energy. Look for opportunity to install fluorescent fixtures with more efficient electronic ballasts.

### **21.3.3. *Identify and Repair/Replace Recessed Lighting Fixtures that Contribute to Building Air Leakage and Compromise Thermal Boundaries***

Most recessed lighting fixtures are not airtight, and cannot be properly sealed or insulated to stop air from leaking between conditioned and unconditioned spaces. These should be replaced by newer airtight recessed fixtures, or with regular ceiling mounted lighting.

### **21.3.4. *Conduct a Refrigeration Appliance Evaluation***

Replacing older refrigerators or freezers (over 10 years) will usually offer significant energy savings. Even a 4-year payback provides for a 25% return on investment.

1. Find and document the model and serial number on a tag in the back interior of the refrigerator.
2. Measure the interior space of each compartment to determine and document the cubic-feet.
3. Plan to hook up a watt-hour meter at the plug socket before starting anything else. Let it measure the actual energy usage while you do other things (minimum 2 hours).
4. Hook up a watt-hour meter at the plug socket for several hours to track actual energy usage.
5. Check the coils on the back of the unit. There needs to be convection that allows for air movement across these coils, and so dust and obstructions may need to be addressed.
6. Consider the positioning of appliances. Placing heating appliances next to cooling appliances is counter-productive. For example, locating a refrigerator right next to a stove/oven combination is a recipe for additional energy usage.
7. Inspect the gasket seals of the appliance. The gasket should firmly hold a piece of paper between the appliance and the door, and offer resistance when an attempt to remove the paper is made. Look for cracks and mold on the door gaskets. Replacement gaskets are usually available from the manufacturer.

### **21.3.5. Evaluate the Use of Flow Restrictors and Low Flow Showerheads**

Flow restrictors and low flow showerheads can reduce the volume of hot water used for personal hygiene and showering. Where many older showerheads can use as much as 5 gallons of water a minute, low flow showerheads are rated to use 2.5 gallons per minute or less.

1. Kitchen and bathroom sinks should be equipped with an aerating screen or orifice in the faucet that restricts flow and mixes air in the water stream. These are usually installed directly at the discharge end of the faucet, and are easy to visually inspect.
2. The flow rate from showerheads can be measured by turning on the shower and capturing the volume of water for a given period of time, in a graduated container (bucket marked in pint increments). If the flow rate for a 20 second period of time is 3 quarts of water, then the flow rate would be 9 quarts per minute or 2.25 gallons per minute flow rate.
3. Consider replacing any showerhead that uses more than 2.5 gallons of water per minute.

### **21.3.6. Maintain and Utilize Diagnostic Equipment in the Evaluation of Baseload Systems**

The equipment that is used to analyze energy usage tends to be delicate and needs to be maintained properly to give true readings. Always follow the manufacturer's suggested maintenance schedule *to the letter*.

1. If an appliance wattage use is not available, measure the amp draw and multiply the amps times volts, to determine the wattage.
2. Use a short piece of 12 or 14 gauge extension cord, with the outer insulation removed and the wires separated. DO NOT remove the insulation on the individual wires. Plug the appliance into the extension cord and the extension cord into the power outlet. Clamp the ammeter around one electrical wire of the extension cord and operate the appliance. Note the amp draw at the startup of the appliance and after the appliance has been operating for a period of 20 seconds or so. Compare the operating amp draw to the appliance rating, if known. Motor driven appliances may be using more amps if the motor or compressor is dirty or worn.

## 22.0 Analysis and Presentation Practices—Prepare For Calculations

### 22.1. Scope

Once you've done the testing, you will have to analyze the data and perform calculations to determine the costs and benefits for purposes of making decisions and proposals on issues that will affect health, safety, comfort, building durability, and energy savings. This should include an evaluation of the original sizing of equipment, as well as existing ventilation rates. You will be required to perform a sequence of calculations to ensure a meaningful analysis as part of a specific audit; the customer demands will be important as well. If you are going to make energy savings recommendations, you have to be able to do energy savings calculations.

### 22.2. Tools and Materials

Building modeling software specifically designed to produce energy savings results

### 22.3. Procedure

#### 22.3.1. **Collect Energy Cost Data**

How much does energy cost in your local marketplace? You can regularly obtain updated energy *per unit cost* information from your state or utility.

Convert this energy cost information into a normalized *Unit cost per Btu*, so you can determine the relative value of different fuels. In order to make this comparison you will want to understand which combination of fuel type and equipment is most cost effective at delivering 1 million Btus.

For example, natural gas is measured in units called therms. A therm represents 100,000 Btus of fuel. To figure out the unit cost of a therm in your area, divide the dollar amount of a recent utility bill by the total therms used. This will give you a unit cost per therm, typically a number around \$1 per therm. Determine the number of therms in one million Btus and multiply the unit cost by that number. That is the cost of natural gas per million Btus. You can compare this to the cost of oil per million Btus.

You can also include system fuel efficiency in the comparison to help determine which heating/cooling system improvement should be made. Divide this cost per million Btu figure by the efficiency (e.g., AFUE, seasonal energy efficiency ratio [SEER]) of the system to get the cost of energy per million Btus. For example, you might recommend an oil furnace that is 84% efficient, but for the same customer you might also recommend a propane gas furnace that is 95% efficient.

#### 22.3.2. **Collect Heating Degree Day and Cooling Degree Day Information For the Related Service Territory**

Heating degree days define the amount of time the average temperature is below 65°F. Cooling degree days define the severity of the cooling season weather by measuring the air temperature difference between the outdoors and 78°F.

Normal monthly and daily weather HDD and CDD information is available from the National Climate Data Center at:

<http://cdo.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl>

This information will help you understand how heating and cooling energy are used throughout the year in your climate.

Up-to-date daily HDD / CDD information is available from the University of Dayton Temperature Data Archive website:

<http://www.engr.udayton.edu/weather/> This site contains files of daily average temperatures for 157 U.S. and 167 international cities. These files are updated on a regular basis. Utility bills rarely line up exactly with the start and end of a month therefore daily weather data is much more accurate in determining the effect of weather on energy bills.

### **22.3.3. Select a Modeling Tool For Energy Calculations**

Energy calculations can be complex and difficult. But there are computer-based building modeling tools that can do this work for you. The Home Performance industry will see increasingly complex modeling continue to boost efficiencies. But meanwhile, there are some basic characteristics of tools that should be considered when you select a building modeling tool:

- Range of improvements available – energy, ventilation, health and safety
- Ability to combine improvements – both within a single model improvement and across a package of improvements
- Ability to create and analyze multiple improvement scenarios
- Accuracy – hourly models are best
- Ability to true-up to actual billing data
- Suitability for load calculation
- Ability to produce useful reports – integration with a custom report tool is best

A comprehensive list of modeling tools can be found at the US Department of Energy website:

[http://www.eere.energy.gov/buildings/tools\\_directory/](http://www.eere.energy.gov/buildings/tools_directory/)

The Home Energy Saver is a free modeling tool that is available via the Internet (<http://hes.lbl.gov/>). This tool is designed to help consumers identify the best ways to save energy in their homes, and then identify the resources to make the savings actually happen. The Home Energy Saver is sponsored by the U.S. Department of Energy (DOE), as part of the national ENERGY STAR Program for improving energy efficiency in homes.

### **22.3.4. Select a Tool for Energy Bill Analysis**

Energy billing data is most often analyzed using a spreadsheet. Spreadsheets allow you to enter individual utility bills into a summary sheet and then do calculations such as determining the heating and cooling energy use, and the baseload energy use. Spreadsheets are also good at

creating charts that allow you to present visual information on current energy use to your customer.

More sophisticated energy billing analysis tools use regression analysis to weather normalize energy use and to more accurately determine heating and cooling energy use. Weather normalization will allow you to compare energy use data from different time periods.

Some modeling tools include billing analysis. This integration of billing analysis with energy modeling speeds up the process of adjusting an energy model to match actual energy usage.

Several billing analysis tools can be found at US DOE:

[http://www.eere.energy.gov/buildings/tools\\_directory/](http://www.eere.energy.gov/buildings/tools_directory/)

### **22.3.5. Prepare to Maintain Records of All Testing, Proposed Workscope, and Support Documents**

You will want to make photo-copies of everything that's relevant to each analysis. Customers should get appropriate documentation pertaining to your recommendations, but they should not get copies of all of your information. Providing too much information can delay a final decision on improvements by the customer.

A well-organized filing system is a big time saver as your business grows. For example, if the customer calls you a year after services have been rendered to ask questions, you will want to have the basic information readily available to you - so you don't have to make a second house call to answer a basic question. Having this documentation will help provide you with repeat customers, and long-term revenues. This includes both digital and paper records. A simple directory structure that stores information first by the last name and then first name is easy to understand and use.



## **23.0 Analysis and Presentation Practices—Conduct Billing Analysis**

### **23.1. Scope**

In the process of analyzing data collected during a home performance audit, you'll investigate the actual energy use of a building, and compare it to other buildings in this and other climates. The actual energy use will serve a realistic limit on over predicting energy savings and will provide early guidance on the potential for saving energy in a building. For example, if there is a high baseload energy use, you will look harder for baseload energy savings opportunities. Performing a billing analysis prior to inspecting the house or while still at the house will allow you to focus more on areas of greater savings.

### **23.2. Tools and Materials**

Spreadsheets, local weather data, and a building modeling tool.

### **23.3. Procedure**

#### **23.3.1. *Collect Utility Bill Data***

Actual energy usage from utility billing data is the foundation for making all energy recommendations. It is worth the effort to acquire this necessary data, even if you need to get a release from the utility company. Monthly billing data contains more information than an annual summary. Some estimate of annual usage is an absolute minimum. Energy modeling tools are much more accurate when adjusted to match the actual energy use of the house.

If a utility requires a signature, consider sending out an inspection confirmation letter that contains a billing data release and a self-addressed stamped envelope. This will allow you to start the process of obtaining billing information.

If internet access to billing data is available, consider sitting down with your customer and having them access their billing data online then send you the information in an e-mail.

Information may also be available on hard copy bills. Consider asking your customer to help out by copying this information on to a form or providing you with photocopies of these.

#### **23.3.2. *Determine the Baseload Energy Use and the Temperature-Dependent Energy Use***

The baseload energy use is the energy usage that is not dependent on the outside temperature. Even though there may be some variation in lighting and domestic hot water due to outside temperature (or season in the case of lighting), you can simplify the analysis process by assuming these energy usages are not temperature dependent.

A standard technique for calculating baseload energy use is to take the average energy use across three months where there is no heating or cooling energy being used. The annual baseload energy use is that average times 12 (months).

The temperature dependent energy use (heating and/or cooling) is the monthly energy use minus the average monthly baseload energy use.

Getting these baseload energy use numbers into charts and graphs will make it easier to generate quick feedback on the improvements proposed, as well as those actually made.

### **23.3.3. Calculate Heating and Cooling Energy Use for the Building, Normalized for the Heated or Cooled Area**

Convert the total energy use from units of energy (for example "therms") into Btus. Divide this by the total square footage of heated or cooled area to get the total Btus per square foot.

Definitions of what constitutes conditioned space vary. The heated area includes all the floor area that is intentionally heated. If the space drops below 60–65°F during the winter, it is probably not a conditioned space. For cooling spaces, if the temperature goes above 82°F, the space should not be considered conditioned.

This will allow you to compare the energy use of this building to other buildings in your climate.

### **23.3.4. Compare Weather Normalized Energy Use to the Weather Normalized Energy Use of Similar Buildings**

In order to compare the energy use of this building to the energy use of buildings in other climates, you must first weather normalize the billing data. This weather normalized value is referred to as the energy index of the building.

This is best done by a dedicated spreadsheet or building modeling tool based on the actual total heating degree days (HDD) and cooling degree days (CDD) during the time period of the billing you are analyzing. The energy index is the total Btus per square foot divided by the total HDD or CDD. If your building has a significant heating and cooling load you may want to determine a separate heating energy index and cooling energy index.

The federal Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS) can be used as source for normalized energy data:

<http://www.eia.doe.gov/emeu/recs/>

## 24.0 Analysis and Presentation Practices—Conduct Base Building Calculations

### 24.1. Scope

After performing a home performance audit and collecting the data required, you'll need to perform a series of calculations as part of making your recommendations. Most of the fundamental calculations can be performed by the building modeling and load calculation software you select. However, it is important that you understand what calculations are being performed so you know the data to collect, and can properly interpret the results.

### 24.2. Tools and Materials

Building modeling software.

### 24.3. Procedure

#### **24.3.1. *Calculate the Volume and Surface Areas of the Building, Relevant to the Test***

Calculate the volume of the building so you can apply this number to your Blower Door test results. It is also necessary for calculating the air changes per hour (ACH). The surface area may be valuable when calculating leakage per square foot on a normalized basis and when doing job cost estimates.

#### **24.3.2. *Build a Software-Based Building Model of the Home***

This process will help you to understand the relative impacts of different energy consuming components of the building. The first step is to model the building as it currently uses energy; the "base building".

When learning to use a modeling tool, experiment with different modeling input choices so you can learn what level of detail is important for different building components. For example, although it's important to be reasonably accurate, obtaining the exact R-value of a door will not change the total energy consumption of a building by more than a few dollars. Some experimentation will help you speed up and focus you in on what is important—in both data collection and data entry.

When building your base model, consider the following in order to make sure that you have a comprehensive model.

- **Surfaces:** Determine the R-values of each surface that makes up the thermal envelope of your building. These would be the surfaces that are adjacent to the outdoors, the ground or to any unconditioned spaces (e.g., an attic or a crawlspace).
- **Air Leakage:** Determine the air leakage/infiltration rate of your building. This is one of the most sensitive model variables, slight changes in this can have large impacts on the building heating and cooling energy usage. If your modeling software allows for it, separate air leakage rates for conditioned and unconditioned spaces. The most accurate way to determine this is by conducting a Blower Door test.

- Fenestration: Determine the surface areas, orientation and U-values of the windows and doors of your building. If your modeling software allows, input the factors that affect the solar gain and shading of the windows. This has a larger impact on energy usage for cooling dominated climates.
- Cooling and Heating Systems: Determine the type, size and annual efficiencies of both systems. The efficiencies should be determined from both in-field testing and using the manufacturer's ratings. Determine the types and efficiencies of the distribution systems. The efficiency will be based on what portion of it lies outside the thermal envelope of the building, its surface area and the effective insulation value.
- Mechanical Ventilation System: Determine the types of mechanical ventilation in the building, their capacities (usually measured in cfm) and their run times. While it is not always possible to measure these, good estimates are needed as this impacts energy usage and can have a big impact on health and safety issues.
- Baseload: The baseload energy usage is comprised of hot water production, appliances and lighting. Hot water production is usually the biggest baseload energy user. Appliances and lighting will impact energy use for cooling and heating, and if left out will create incorrect results for heating and cooling.

*When doing these calculations, always use the average interior building temperature, NOT the thermostat setting. A poorly performing building may have wide variations in temperature. Assuming that the entire building is at the same temperature as the thermostat setting may significantly inflate your assumptions of energy use before retrofit and therefore cause you to over predict savings!*

### **24.3.3. True-Up the Building Model**

Once the basic building data has been entered into the modeling, you should compare the performance of your model with actual performance of the building as reflected in the utility bills.

The more detailed your billing analysis, the more valuable the information is in truing up the model to the actual bills. The minimum true-up is to make the total annual energy usage of the model equal that of one year of billing data

If your building model heating/cooling/baseload outputs differ significantly from the actual billing outputs, you may need to look at the billing data, or the model:

True up the billing data:

- If billing data and model usage differ for many bills, you need to true up the model. If only one or two bills are very different from the model, consider the possibility that the data for these bills is not reliable, or that the behavior/presence of the occupants changed.

True up the building model inputs:

- First, match the baseload usages by adjusting your model inputs for hot water, lighting and appliances.

- Second, match the cooling and heating slopes. This is a good true-up for the R-values of surfaces, windows, doors, infiltration and ventilation rates, and cooling and heating system efficiencies. Adjust the model inputs that affect areas.
- Third, match the cooling and heating reference temperatures. Even though the reference temperatures are dependent on internal and solar gains as well as the cooling and heating slope, once the slope is matched, you can focus on getting the internal gains correct. Verify the inputs that are related to internal and solar gains, such as window shading, exposure, and percentage of heat loss to spaces that will not affect the total absolute value of the baseload.

#### **24.3.4. Calculate the Correct Size for the Cooling/Heating Equipment**

Calculate the correct size for the cooling / heating equipment with the current building conditions. Then, adjust building characteristics to reflect the proposed installation measures and determine the proper size for any proposed installation.

In order to establish the correct equipment size, use The Air Conditioning Contractors of America (ACCA) Manual J calculations (or an equivalent tool) to calculate heat loss from the building through the surfaces of the thermal envelope, leaky and/or uninsulated ductwork that is in unconditioned spaces, and/or infiltration through windows, doors, and other surface penetrations. Additionally, use the ACCA Manual J calculations to calculate the heat gain into the building from sunlight, people, lights and appliances.

The design conditions for your geographical area are important inputs into the load calculations.

#### **24.3.5. Evaluate the Performance of the Distribution System**

Evaluate the performance of the distribution system using heat loss/gain calculations based on ACCA Manual D, or an equivalent.

You'll want to look at all the components of the whole house as an integrated system. Sometimes, distribution system issues can be addressed through solving building envelope problems and/or duct leakage issues.

Whether a room-by-room distribution sizing calculation should be done is determined by the overall goal of the analysis. For example, is there a comfort problem with a specific area or the whole house? If so, you will want to try solve this problem by repairing the envelope (as modeled in the software), and then look again at the performance of the distribution system under the proposed retrofit conditions.



## 25.0 Analysis and Presentation Practices—Evaluate Ventilation Requirements

### 25.1. Scope

The ventilation related calculations that you will do are necessary to be able to make decisions and recommendations that include improvements related to the natural and mechanical ventilation rates in the building.

### 25.2. Tools and Materials

Calculator.

### 25.3. Procedure

#### 25.3.1. *Determine the Current and Proposed Pressure Boundaries For Connected Building Zones*

This question should be answered with consideration of health and safety, energy efficiency, and existing conditions. Should transitional spaces (attics, crawlspaces, garages, etc.) be inside or outside the pressure boundary?

- It is important for garages to be outside the pressure boundary - to exclude automobile fumes from the living space.
- Vented crawlspaces and attics are always considered to be outside the pressure boundary.
- Unvented crawlspaces, unvented attics, knee-wall cavities, and basements may be inside or outside the pressure boundary. Whether they are best brought inside or outside (through your air-sealing activities) will depend on presence of radon and moisture, locations of mechanical systems, piping, and ductwork, as well as the location of existing insulation.

#### 25.3.2. *Translate Artificially Created Airflow Rates Into Natural Airflow Rates*

Blower door tests result in a leakage rate at the standard difference pressure of 50 Pascals between the indoors and outdoors. This induced leakage number can be converted into an average or seasonal air change rate. The actual leakage rate will vary through the season. Determine the LBNL “natural” factor for the building, based on its climate zone, location, and number of stories above ground. The LBNL factor represents the impacts of “stack effect,” temperature, and wind on the building. The induced air flow rate represented by cfm at 50 Pascals ( $\text{cfm}_{50}$ ) is divided by the LBNL factor to determine natural building flow rate. The LBNL “natural” factor is derived from the LBNL natural factor chart—usually located in the blower door instruction manual.

- Locate the climate zone you are in.
- Determine the building’s exposure to wind by identifying anything that would buffer the building from direct wind.

- Identify the numbers of stories exposed above grade.
- Measure the volume of the tested living space (in cubic feet). This will be required to convert cubic feet per minute to air changes per hour—which is also a means of measuring leakage rates and ventilation rates for a building.
- <http://epb.lbl.gov/blowerdoor/BlowerDoor.html>
- <http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html>

### **25.3.3. Determine the Amount of Cumulative Ventilation Required For Site-Specific Situations**

Building ventilation standards are based on the requirement to maintain clean, pollutant- and odor-free air for the occupants. The amount of ventilation required to provide this will vary from house to house, depending on building size, number of occupants and occupant lifestyles. Relying on natural building infiltration is not a dependable or cost effective ventilation strategy. A best practice is to make the building as airtight as possible and then, if needed, install a well designed mechanical ventilation system. There are two approaches to determining proper indoor air ventilation. One is a building tightness limit based on ASHRAE 62-2001. The other is a mechanical ventilation requirement based on ASHRAE 62.2-2003.

#### ***Building Tightness Limit Standard***

To determine the building tightness limit and compare it the building infiltration rate, select the larger of the two following calculations, and multiply it by the LBL factor discussed in the section above. This will result in rate in cfm<sub>50</sub>.

1. Each occupant of the building should be provided with a minimum of 15 cfm. In instances where a building is obviously designed for more people than currently occupying, consider a minimum ventilation rate based on 2 persons for the master bedroom and one person for each additional bedroom. If a 3 bedroom home is currently occupied by a single person, base the minimum ventilation flow on 4 potential occupants ( $4 \times 15 = 60$  cfm). This is a good guideline, but ventilation rates must be tailored to reflect the lifestyle of the occupants.
2. Multiply the conditioned square footage of the building and multiply this by the height of the conditioned area. The resulting volume of the conditioned area is then multiplied by 0.35 air changes per hour (ACH) and divide by 60 to get your resultant cfm of air flow.

#### ***Mechanical Ventilation Standard***

ASHRAE 62.2-2003 requires a local mechanical exhaust system to be installed in each kitchen and bathroom. A user-operable vented range hood must exhaust at least 100 cfm of air or five kitchen air changes per hour. Each bathroom ventilation fan must exhaust a minimum of 50 cfm on-demand or 20 cfm continuously. Mechanical exhaust is not required in toilets, laundry rooms, lavatories, and utility rooms.

Almost all houses must have a whole-house mechanical ventilation system rated at 7.5 cfm per occupant, plus one cfm for every 100 ft<sup>2</sup> of floor area that can be occupied. Houses exempt from

this requirement include houses in hot climates without air conditioning, houses conditioned for less than 876 hours per year (e.g., cabins and vacation homes that are occupied for brief periods), and houses in hot dry climates, primarily in the southeast and southwest U.S. where occupants generally ventilate by opening windows.

The standard should be carefully reviewed to comply with the additional requirements it specifies for these mechanical ventilation systems.



## **26.0 Analysis and Presentation Practices—Evaluate Improvements for Inclusion in Packages based on Both Energy and Non-energy Impacts**

### **26.1. Scope**

Calculating costs and benefits will determine how soon your proposed improvements will pay for themselves. But often the benefits cannot be calculated solely on the basis of cost and payback. If comfort or safety issues are involved, the payback period may not be as relevant to the overall proposal.

Consider the proposing recommendations in these areas:

- Health and Safety-related improvement opportunities—For example: addressing lead or mold abatement
- Comfort-related improvement opportunities—For example: addressing air distribution issues, duct leakage
- Building Durability-related improvement opportunities—For example: addressing site-related moisture issues
- Energy Efficiency-related improvement opportunities—For example: addressing insulation issues, heating/cooling equipment sizing and issues, energy savings from appliances and lighting
- Resource Efficiency-related improvement opportunities—For example: solar energy or water savings, or “green” materials choices.

### **26.2. Tools and Materials**

Building modeling software.

### **26.3. Procedure**

#### **26.3.1. *Evaluate Health and Safety Improvements***

Finding and eliminating the source of internal air pollutants, including carbon monoxide, is a first priority. If the pollution source cannot be eliminated for some reason, consider isolating the source of contaminants from the living space through air sealing or ventilating the source.

Determine a ventilation solution from a range of options including point source systems, such as enhanced bathroom ventilation, up to ducted exhaust systems and ducted supply and return heat or energy recovery ventilators. Select and specify mechanical or passive ventilation systems based on specific situations and performance characteristics. Identify locations for the placement of ventilation devices.

Other common health and safety improvements include electrical system improvements, radon remediation, asbestos abatement, mold remediation, moisture reduction and water leaks.

### **26.3.2. Evaluate Improvements Based on Comfort**

Evaluate which improvements will improve comfort. Comfort improvements typically will reduce drafts, deliver more heating or cooling to a space, improve the mean temperature of a space. Comfort improvements will typically also save energy, but may or may not be cost effective.

Load reduction strategies can be used in combination with changes to distribution systems to improve comfort. Recalculation of distribution system performance may be necessary to verify post retrofit performance.

### **26.3.3. Evaluate Building Durability Improvements**

Building durability improvements are often linked to controlling moisture. You can manage bulk moisture by keeping moisture vapor from condensing into bulk moisture. You can reduce moisture vapor into the building by installing ground vapor barriers.

### **26.3.4. Evaluate Resource Efficiency Improvements**

Resource efficiency improvements can include changes to improvement specifications to use more local or recycled materials or reducing the utilization of materials that might have an adverse impact on the environment, such as mercury.

### **26.3.5. Calculate Savings For a Range of Improvements Including Energy Efficiency**

Savings calculations are important advice to provide to your customers and help them to make decisions. Savings calculations are also critical for any external accountability you might have, for tax credits, to access state or utility subsidies, etc. Savings are not the only way that customers make decisions. The initial calculation of savings may be done using cost estimates to identify obvious outliers. After improvement measures are selected, a second savings calculation run can be done using more precise costing to produce a report and an associated proposal.

Sometimes improvements have interactions between various components of the building. For example, if you replace an incandescent light bulb with a compact fluorescent light bulb, you will also reduce the cooling load, while slightly increasing the requirement for heating. Depending on your climate this may have a positive or negative effect on savings from lighting.

Sometimes improvement combinations have synergistic impacts. Insulation saves energy and reduces the heating and cooling load. Adding a new piece of heating or cooling equipment therefore saves less after insulation has been installed. The reverse is also true. The energy model should take into account these interactions. A simple engineering calculation does not.

Your understanding of the interactive impacts will improve over time, and the trade-offs will become obvious. Experiment with the energy model to understand more about interactions and how they work in your climate.

You can use calculations to justify incremental improvement costs. If the decision has already been made to replace windows (if the customer wants to do it anyway), you can use the incremental costs to justify your work putting the windows in properly.

Sometimes improvements have more than one impact on the model, for example, windows. Windows save energy through changes in the R-value of their surface area as well as the through reduced air leakage. This may require you to make changes in two places in the energy model for one improvement.

Maintain a comprehensive list of improvement and energy savings opportunities, and develop an understanding for the savings potential for each improvement within your particular climate. Then, select improvements based on the needs of the building as well as the interest of the customer. The basic categories of energy savings are:

1. Appliances
2. Cooling system
3. Distribution system
4. Domestic hot water system
5. Door replacement
6. Fans for ventilation
7. Heating system
8. Indoor temperature control
9. Infiltration reduction
10. Lighting
11. Renewable energy
12. Surface insulation
13. Window replacement

Evaluate savings by making changes to the energy model to reflect your recommended changes for each improvement type.

With all these improvement possibilities, the question boils down to “what should be calculated?” For each building, start by making a list of the savings opportunities. You will need to reconcile the improvement opportunities with the customer’s basic interests.

If you are just starting out, try calculating the savings based on a best guess price for the improvement. You can go back and change the guess into a precise number later. Calculating the cost of improvements is generally more complex and time consuming than calculating the energy savings opportunities. So if an improvement does not save energy, then it does not always make sense to take the time to figure out what the costs will be.

Consider load reduction improvements before heating and cooling system improvements.

### **26.3.6. Calculate the Simple Payback for Recommended Improvements**

Simple payback is calculated by dividing the cost by the savings generated during the first year after the improvement.

Simple payback is understandable for many homeowners, but may not be the most reliable indicator of savings performance. It does not take into account the life of an improvement or changes in the cost of energy, for example.

### **26.3.7. Calculate Life Cycle Benefit/Cost Relationships for Recommended Improvements**

Life cycle cost calculations give a more detailed view of cost/benefit relationship. In life cycle cost calculations, you compare the cost of an improvement to the savings over the entire life of the improvement. For example, if a customer's heating system has fuel costs of \$1000.00 per year, and you propose to replace the heating system with a unit that will reduce fuel costs to \$500.00 per year and last 25 years, then you can calculate a savings of \$12,500.00 over that same period. But this calculation does not take into account the time value of money. Savings gained this year are worth more right now than the savings that will occur 25 years from now.

A common standard for life cycle cost calculations is the SIR (savings to investment ratio). The SIR is a method of evaluation that expresses the ratio of savings over the entire improvement life to the cost of installation. It compares investing in the improvement versus investing in a bank CD (or equivalent investment) for the term equal to the life of the improvement – and will also account for fuel cost inflation. An SIR greater than one indicates that the improvement makes economic sense. Standard inputs include: the cost of fuel, the inflation rate, percentage earnings on an equivalent investment, and term of the life of the measure. This is a complex calculation that may be best handled by a software tool.

## **27.0 Analysis and Presentation Practices—Create a Customer Report**

### **27.1. Scope**

When creating a report of your findings, you will want to include an analysis of the energy billing data, as well as educational information and digital pictures of areas needing improvement.

The report is important because it helps maintain your consultant relationship with the customer, even as you recommend work to be performed by your own company. Neglecting the quality of the report will create distrust. On the other hand, the report is costly, so spending too much time on writing and producing a report may not be productive.

You will want to establish a system for quickly producing reports and proposals that have an adequate level of information. Your reports can include standardized chunks of text, but must be clearly specific to the customer's building. Using a report writing tool that works with an energy modeling tool is one effective way to do this.

Your final report should be legible, with no misspellings, and professional in nature.

### **27.2. Tools and Materials**

Report templates, customer report generating tool, word processing tool.

### **27.3. Procedure**

#### **27.3.1. *Provide a Description of the Building's Current Condition***

Use a standardized written report that follows an industry-accepted form and content. The report should contain the results of tests, with explanatory text, photos of the building, links to educational information, etc.

Proposed category headings should include the following:

- Air Leakage
- Insulation
- Heating System
- Cooling System
- Domestic Hot Water System
- Health and Safety Information
- Appliances
- Lighting

You'll want to include recommended values as compared to observed or measured values in these sections to prepare your customer for your proposal of improvements.

NOTE: Not all the information you collect will be appropriate for the customer. Your report should be a condensation of your findings—designed to frame the primary issues discovered in the audit.

### **27.3.2.        *Identify Health and Safety Issues***

Emphasize actions that need immediate attention, and make them a pre- requisite for the other improvements you are recommending.

If there are serious health or safety issues involved, these should be discussed with the customer as soon as they are confirmed, and certainly before your report is delivered.

### **27.3.3.        *Show Where Energy Is Currently Being Used in the Building***

Provide the results of the billing data analysis in a graph that shows the relationship of energy usage from one month to the next over an extended period of time.

Illustrate the breakdown of where energy is currently being used as predicted by energy model. A pie chart is a good way to depict energy usage so that the customer can understand the model.

### **27.3.4.        *Identify Any Incentives Available***

If there are incentives or rebates that are part of government- or utility- sponsored programs, the details should be clearly spelled out. These can have a dramatic impact on the project's return on investment.

Be sure to check the DSire database of incentives for renewable energy and energy efficiency. <http://www.dsireusa.org/>

Financing options should be spelled out as well. If financing options are made available, these will have a huge impact on your sales closing rate, as they can help customers handle cash-flow issues that might otherwise keep them from moving forward on your recommendations.

### **27.3.5.        *Provide a List of Improvements With a Description of Each***

Explain each improvement in general terms.

Depending fully on what you have learned and what issues exist, you'll want to address improvements as necessary - in the following areas (and in roughly this order):

- Air Leakage
- Insulation
- Heating / Cooling System
- Domestic Hot Water System
- Health and Safety Improvements
- Appliances
- Lighting

For each improvement, you'll want to include a short title and a fairly detailed description, with both energy-related benefits as well as non-energy benefits (for example, the non-energy benefits of air sealing include improving comfort and increasing the value of building).

**27.3.6.        *Recommend Packages of Improvements Based on Various Levels of Investment***

Providing your customer with a couple different packages of improvements can simplify the sales process and deter the customer from choosing improvements *a la carte*.

Show the interacted individual improvement savings for each improvement in a package and the savings performance of each package as a whole. Show the performance of each package compared to the monthly payment of a typical energy loan.

Organize the packages so that any required health and safety improvements are part of each package.



## **28.0 Analysis and Presentation Practices—Estimate the Cost and Proposed Price for Recommended Improvements**

### **28.1. Scope**

When making decisions about what costs the customer (and the project) will bear, you will be combining three major elements to define the economics of your recommendations:

- Savings calculations for improvements
- Specifications and equipment choices for improvements
- Job cost estimation for improvements

As part of this triangulation, you will need to process this data in a way that will make sense to the customer.

### **28.2. Tools and Materials**

Cost estimating tool, estimate pricing guidelines, word processing tool.

### **28.3. Procedure**

#### **28.3.1. *Select Methods in Accordance With Building Codes and Industry Standards***

1. Building codes, energy codes, fire codes, and electrical codes are generally localized and need to be considered when determining the tactics that will be used to implement improvements.
2. Work with your local code officials to determine what projects need pre-approval, and what the process is for getting it.

#### **28.3.2. *Define the Installation Standards and Specifications for Proposed Measures***

To be successful, you'll need to have standard procedures for installation.

There are many industry resource websites that provide direction and resources for standards:

- ACCA—The Air Conditioning Contractors of America helps contractors acquire, serve and satisfy their customers. [www.acca.org](http://www.acca.org)
- NARI—The National Association of the Remodeling Industry supports remodelers in a wide variety of ways. [www.nari.org](http://www.nari.org)
- NAHB—The National Association of Home Builders is a trade association that helps promote the policies that make housing a national priority. [www.nahb.org](http://www.nahb.org)
- CIMA—The Cellulose Insulation Manufacturers Association represents the technical, scientific and professional interests of manufacturers of cellulose insulation materials. [www.cellulose.org](http://www.cellulose.org)

- ICAA - The Insulation Contractors Association of America is a trade association whose site includes a "Contractor Locator," along with a database of residential and commercial thermal insulation contractors, searchable by ZIP code. [www.insulate.org](http://www.insulate.org)

You will want to keep this information handy, and connect with these organizations at some point.

### **28.3.3. Identify the Materials and Equipment Specifications For Each Measure**

Specification is about selecting products that meet the needs you've identified. Sometimes this will require making complex decisions. For example, what kind of cooling system is most appropriate? You'll use the manufacturer's specifications and the cost of each product, to balance this against the savings being generated. You should include the savings calculations in the specification process. For example, you'll need to be able to determine how much energy will be saved by putting in a cooling unit with a higher SEER.

It's not always *just* about cost-effectiveness. Customers may have specific brands or features that they prefer. Or they may be interested in green materials.

There's also quality and availability to consider.

You'll want to develop a relationship with your suppliers, so you trust them and they trust you. You'll also want to develop a list of manufacturers' catalogs and make sure you are on their mailing lists when these catalogues are updated.

As you scope out the need for materials, try to limit the choices so that you can limit the types of products the crew needs to know how to install.

Know your market and select materials and equipment accordingly.

Be sure to take into account the maintenance required by products. New products have an "unknown potential" requirement for maintenance.

### **28.3.4. Calculate the Materials and Labor Costs Associated with Proposed Measures**

Develop unit pricing where possible. For example:

- Dollars per square foot of insulation,
- Dollars per air conditioner or furnace installed of a specific size, etc.

Modify your established unit prices based on job difficulty, complexity, distance, and maybe even customer characteristics. For example, potential problem customers might pay a little more (they will cost you more).

Maintain materials and equipment costs in a database, and update them regularly to reflect changes in costs.

Always reflect the true cost of labor, including benefits and workman's compensation.

**28.3.5.        *Incorporate the Cost of Overhead Into the Estimation Process***

Know what your cost of overhead is and add this and your profit margin to the cost estimate in order to get a proposed price. The profit margin is the difference between the price charged by a company for its products or services and the cost of producing them. A reasonable profit margin is imperative. Typical margins are 40% to 50%.

**28.3.6.        *Routinely Compare Actual Profits to Estimated Profits***

You will need tracking systems to do this. Tracking can be in any form (paper or electronic) but must be consistently maintained. This will provide a feedback loop that will ultimately let you know how you are doing, and allow you to improve.

Track materials and labor and subcontractor costs individually.



## **29.0 Analysis and Presentation Practices—Create a Customer Proposal and a Workscope**

### **29.1. Scope**

The proposal is where you make it clear to the customer that you can do the recommended work, and specify what it will cost. The proposal can also function as a contract, at which point it becomes a legal document (and the components should be developed with the support of a lawyer).

The workscope will be used by the crew as they enact the recommended improvements. They will need clear direction on the work required, and this should include any information or pictures that might help to clarify the details.

The proposal and the workscope should probably be created as part of the same process, since the ability to remember the details—of the existing building, as well as the details of the recommended improvements—will be critical to getting it right.

### **29.2. Tools and Materials**

Report templates, customer report generating tool, word processing tool.

### **29.3. Procedure**

#### **29.3.1.        *Develop a Customer Pricing Proposal***

Develop a pricing proposal for enacting the recommended improvements, highlighting issues that will have an impact of health, safety, comfort, energy use, or building durability issues.

Use price estimates developed previously, and include a payment schedule that is simple and phased with the work being performed.

Use standard contractual language, developed with the support of a lawyer, and specific to the local requirements of your county and state.

Warranty obligations and limitations should be spelled out clearly, leaving no unmentioned assumptions. General liability limitations (for example; moisture issues) should be highlighted.

Avoid proposals where the customer or someone else (not your subcontractor) does some of the work. Too much potential for problems.

#### **29.3.2.        *Present the Pricing Proposal to the Customer***

Your proposal can be delivered in several ways.

- By e-mail (use an Adobe PDF format so you will know if anything has been edited). This take less time to deliver, but will also lower your closing rate.
- In person, you'll have a higher closing rate, but more time is required.

You should vary your presentation delivery based on your backlog and the customer.

### **29.3.3.        *Develop a Crew Workscope***

Develop a workscope that provides the installation crew with site specific information that will support a quality installation.

Get this info recorded while it is still fresh in your mind.

Since analysts are sales oriented and may not be as technical, another visit may be necessary before the crew shows up at a sold job. This visit can be used to finalize measurements and make sure all materials are available as well as confirming the workscope with the customer.

### **29.3.4.        *Retain Information to Allow its Retrieval If the Customer Delays Implementation***

You will need a storage system and a naming convention that makes it easy to find critical customer data when it is required. Storage systems such as alphabetical directories can be tied to Customer Relationship Management (CRM) systems for following up on unsold jobs.

## **30.0 Installation Practices—General**

### **30.1. Scope**

Start with a plan and be sure you can follow-through. Make sure that your customers understand and sign off on your plan. Make sure they understand the expected results and any known uncertainties. Once you've started implementing your plan, the most important thing is to be sure to address manufacturers recommendations and local codes as well.

### **30.2. Tools and Materials**

TBD

### **30.3. Procedure**

#### **30.3.1. *Maintain Safety and Cleanliness in the Work Area***

1. Keep occupants, especially children, away from any area under construction. If possible, isolate the room where work is being performed by closing doors to the main living area. This will also help contain debris that may be contaminated with lead.
2. Install a polyethylene drop cover on the floor and around the window, to collect dust and debris that may result from handling the existing window framing. Drop cloths should extend 5' beyond the work area in all directions, and should be taped securely in place.
3. Installers should wear NIOSH approved dust masks or respirators and disposable shoe coverings. In high dust conditions, protective disposable coveralls should also be worn.
4. HEPA filtration type vacuum cleaners should be used to remove loose paint and dust from the window components, especially in the window well area, before work is started. When the existing windows are removed, wind and air currents can drive uncollected dust further into the living area.
5. Use water to mist the surfaces of any painted material to be handled. Add a couple drops of detergent to give weight to dust particles and help control dust movement in the air
6. When you are finished, carefully roll up the drop cloth and place the heavy mil plastic bag into a second plastic bag, with any other waste from the installation. Secure tightly and remove the plastic bag from the building. Vacuum (HEPA) all surfaces in the area of the window, including the floor, walls, interior casings. Damp-mop or clean all interior surfaces in the vicinity with a detergent based product.

#### **30.3.2. *Provide Installation Instructions and Standards For Each Measure***

Installations should also always be accomplished in accordance with the manufacturer's installation instructions, industry standards, and local building codes. For long-term business reasons, you'll want to establish your own standards and then stick to them. For example, when installing a straight run of pipe for make-up air, consider putting an "S"

shaped trap into the system to reduce the possibility of back-drafts. Another option might be to use a power-assisted ventilation system if the zone is not balanced without punching a hole in the wall.

### **30.3.3. Provide Materials Application in Accordance With Industry Standards and Building Codes**

This is important for the industry as well as for your individual business reputation and the repeat customers it will bring that you want to attract.

Make-up air requirements for the combustion appliance zone are defined by an NFPA (National Fire Protection Association) code. Installations should also always be accomplished in a manner that assures air tightness of the installation, while protecting yourself, the home, and the occupants from the potential of harmful exposure through paint and dusts, or changes in building pressure that may cause problems after you are gone.

### **30.3.4. Balance Zonal Pressures that Exceed Action Levels**

The action level for conditioned zones is 3 Pascal. For unconditioned zones, this action level is relative to the amount of air leakage to with the outside. Set the each zone up in such a way as to test the cfm flow across the pressure boundary.

In a conditioned zone, air pressure is a function of the amount of leakage to the outside. If an attic is very tight, it doesn't take much to affect the air pressure. For example, if a house creates 4 Pascal of pressure in the attic when an air handler comes on, this might seem high. But if the attic has substantial air leakage, then it would will take quite a bit of air to bring the pressure difference to 4 Pascal.

To deal with balance zonal pressure balances that exceed action levels:

- Add a vent to a nearby wall.
- Change the venting to power-assisted.
- A barometric damper will allow the vent to open and close whenever necessary.

In unconditioned space— with the exception of the combustion appliance zone—the pressure balancing strategy would be to air seal the leaks between the conditioned and the unconditioned space.

Where atmospheric appliances are in use, the pressure balancing strategy would be to provide enough air that even under worst-case scenario, the appliance meets venting standards, doesn't back-draft or produce carbon monoxide. This is possible by providing a make-up air vent from the outside. To determine how much make-up air is necessary, try opening a window and measuring the difference.

## 31.0 Installation Practices—Windows

### 31.1. Scope

Replacing windows often has a low savings-to-investment ratio because of the high cost per square foot, when compared to a relatively small impact on Btu savings—based on conductive gains and losses. For homes with well-defined thermal and pressure boundaries, the portion of heating and cooling load that accrues from window glazing will increase.

Window replacement decisions should always be based on the cost of the installation (materials and labor) as well as the ability of potential savings to offset the installation costs. Other factors that should be considered include the potential for reduced air leakage, the condition of the existing windows, and maintenance requirements as well as noise control, ease of operation (for ventilation), security, looks, resale value, etc.

### 31.2. Tools and Materials

Level, drop cloth and heavy mil plastic bags, a blower door tester, diagnostic smoke generator, HEPA filtration type vacuum cleaner, water in spraying container.

### 31.3. Procedure

#### 31.3.1. *Select Replacement Windows*

Replacement windows should be constructed of a material that limits conductive gains and losses through the frame and sashes. Vinyl or wood performs much better than aluminum, although some aluminum frames contain a thermal break to interrupt heat transference.

1. Replacement windows that are designed to be inserted into the frame of existing windows are recommended, because of the relative ease of installation. Significant material and labor savings are realized when the existing frame and casings do not need to be disturbed. Unless the existing frame is wood or vinyl this should not be recommended since condensation issues will depend on frame exposure. Note that glazing size is slightly reduced with a replacement insert.
2. The glazing space selected should be of ½" or greater between glass panes. LBNL research indicates a 20% improvement in conductive properties over a ¼" spacing between glazing panels.
3. The U-Factor is the measure of the thermal transmittance, averaged for the frame, edge of glass and center of glass. The lower the U-Factor, the better the insulating performance of the window. The IECC minimum standards for U-Factors are: .U -.4 in climates of less than 3500 Heating Degree Days and U-.33 in climates over 3500 HDD.
  - Standard U-Factors for typical glazing include;
    - Single glazed window U = 1
    - Double glazed window U = .5
    - Low-E window U = .25 to .35

4. Solar Heating Gain Coefficient (SHGC) represents the % of solar energy that is gained through the glazing under test conditions. For climates with less than 3500 HDD, a SHGC of .4 or less should be considered.
5. Windows should be rated by the National Fenestration Rating Council; an independent agency responsible for testing the performance features of windows. Windows that are not rated by NFRC may not actually perform to the manufacturer's specification.

### **31.3.2. *Install Replacement Windows***

Window installations should always be accomplished in accordance to the manufacturer's installation instructions, in a manner that assures air tightness of the installation, while protecting the installer, the home, and the occupants from the potential of lead exposure through paint and dusts.

1. Keep occupants, especially children, away from any area under construction. If possible, isolate the room where work is being performed by closing doors to the main living area. This will also help contain debris that may be contaminated with lead.
2. Carefully remove window stops, sashes, parting beads, casings (if necessary), etc., and place in heavy mil plastic bags. Include any material that will not be included in the installation of the new window. Do not saw or create excessive dust from any of the original painted materials.
3. Prepare the window opening by installing new window stops, replacing any deteriorated framing material and cleaning/painting any raw wood surfaces that will be exposed to weather.
4. Use a high-quality sealant along the inside surface of the exterior window stop and across the sill to air seal the replacement window.
5. Install the replacement unit tightly against the exterior window stop. If the window is not the exact opening size, use an expander along the top of the unit to modify the size of the window unit. Secure the window unit to the jamb stops in accordance with the manufacturer's instructions. Use a level to insure the window is plumb and level before permanently fastening.
6. If the window installation requires the removal of the existing window frame, use one-part non-expanding urethane foam to seal gaps between the window and wall frame, as well as any un-insulated wall cavities. Do this prior to reinstalling the interior window casings.
7. Pressurize the living space with a blower door and use a diagnostic smoke generator to check for a positive air seal around the completed installation.

### **31.3.3. *Air-Seal Existing Windows***

When replacement is not an option, existing window units that are in good working order can usually be effectively air-sealed. Analyze the existing air leakage by creating positive pressure

in the living space (using a blower door tester) and then look for specific leakage points using a diagnostic smoke generator. Check around each sash, as well as window pulley systems and interior casings, for smoke leakage.

1. Trim any surfaces to be weatherstripped, so as to accommodate the additional width of the material. If this requires disturbing existing painted surfaces, i.e., planning or sanding, be sure to perform this treatment outdoors, away from populated areas. Figure out a way to contain all dusts and debris.
2. Prime any unpainted wood surfaces prior to installing weatherstripping.
3. Select the weatherstripping material most appropriate for the specific window. Compression-type vinyl v-gasket works well for jambs and rails of double hung windows. This may have an adhesive but it is recommended to use ¼"-staples to secure the v-gasket to the jambs, sills and check rails. The V should open in the direction of the outdoors.
4. Non-operating components of the window can be sealed with a clear or paintable acrylic based latex sealant. Do not use sealants high in volatile organic compounds on the interior of the building, as many customers are sensitive to the odors.
5. When casings, aprons and window stools have been removed, seal *within* the building frame using one part non-expanding urethane foam. Minor leaks may be addressed by sealing *around* these components, but the effectiveness is not guaranteed.
6. Pulley systems that are operable can be sealed at the jamb with pulley seals that allow for the associated ropes. If the system is not operable, the opening in the jamb can be permanently sealed.
7. Pressurize the living space with a blower door and use a diagnostic smoke generator to check for a positive air seal around the completed installation.



## 32.0 Installation Practices—Moisture Control and IAQ

### 32.1. Scope

For healthy indoor air quality, moisture must be factored into an equation along with Volatile Organic Chemicals (VOCs), gases present in the soil, and more. Your response to pollutant sources and strengths in the building is dependent on accurate diagnosis and a clear understanding of the options available.

Whenever feasible, a pollutant source should be removed from the building. Removing strong chemicals from the living space is preferable to providing additional ventilation to preserve air quality. If removing the source is not possible, then you'll need to be clear on the strengths and limitations of available options around encapsulation, ventilation and de-humidification.

When it comes to mold, preventing water from intruding into the building is a far better strategy than using dehumidification to maintain reasonable humidity levels. Other biological growths can be more challenging to identify. Keeping the household and air handlers clean, and controlling humidity are effective remediation techniques that cost very little to implement.

Ultimately, your recommendation must be resolve the problem it is intended to correct, and you are well advised *not* to cut corners (or under-design a remediation project) in an attempt to offer a "low bid." Some "surface mold" cleanup jobs can challenge the average contractor, and may still require the services of a professional engineer, hygienist or remediation specialist.

### 32.2. Tools and Materials

TBD

### 32.3. Procedure

#### 32.3.1. *Identify Area Where Molds and Other Biological Growths Appear*

Locating mold growth in a building generally requires a detailed visual and olfactory inspection. Usually the greatest concentration of moisture is located near the point of origin. But you must consider the scope of the identified areas as well as air patterns that might carry mold elsewhere. Finding the root cause (temperature/humidity problem) must be accomplished before any cleanup, removal and renovation will be effective.

1. Visually inspect for discoloration, deterioration of materials and smell for earthy, musty or alcohol odors. Do not disturb molds or dusts during your inspection.
2. Identify suspect mold growths by placing a chlorine bleach solution (or X-14) on a small area. A resulting color change usually indicates mold while no color change usually indicates dirt or something other than mold.
3. Once the source is identified, a practical remediation strategy must be identified. Be sure to identify whether the mold is a surface problem or has moved deeper into the building components.

4. Are the building materials associated with the mold colonization salvageable, or will they require removal? Contamination of absorbent materials such as drywall or insulation is best handled by removal/replacement. Wood can be salvaged if treatment precedes any actual decay.
5. Have personal possessions or building contents been affected by mold colonization? A determination will likely need be made about what is salvageable and what needs to be discarded.

### **32.3.2. Correct Moisture Problems in Wet Crawl Spaces**

Where excessive moisture manifests as mold in crawlspace, it is likely that the soil around the building is damp. Even dry soil contains and can release quite a bit of moisture into the conditioned space via “stack effect.” Crawl spaces should be cleaned out, and then a layer of 6-mil poly laid down and tacked.

1. Roof gutters and downspouts must be designed to collect roof run-off and divert it away from the ground around the foundation.
2. The foundation should be adequately waterproofed where it is in contact with the ground - or provided with a drainage plane to isolate the masonry from the soil. Plastic sheeting, foundation insulation, or specially designed drainage plane material may be effective treatments for below grade situations.
3. Crawl spaces should be protected with a water impermeable ground cover, such as heavy 6-mil poly or EPDM (Ethylene Propylene Diene Monomer) material, generously overlapped at the seams, weighted into place and sealed around the edge using polyurethane caulk or by power-nailing the edges with furring strips to the foundation wall.
4. Ventilation of crawl spaces should be attempted only when ambient air is dry enough *not* to condense in the cooler crawl space areas.
5. Dehumidification may be an effective strategy for controlling occasional high humidity but should not be the principle strategy for controlling bulk moisture issues.

### **32.3.3. Set or Adopt Standards for Practices and Limits on Mold-Related Correction Work**

Correcting existing mold problems may be as simple as installing an exhaust ventilator in laundry room, or as complicated as disinfecting an entire building. It is important to decide what level of service you can effectively provide and when to call on a remediation specialist. Some mold remediation work will require extra health and safety precautions, specialty equipment and a lot of attention to detail. Regardless of the care taken, it is often difficult to predict the effectiveness of your completed work. The cleanup associated with larger mold contamination jobs can be dangerous, tedious and time consuming.

Consider the following:

1. At what point should you consider bringing in a specialist in mold clean-up? Smaller “surface mold” jobs that address isolated or regional areas of the building may be reasonably uncomplicated, while some mold contaminations involve the whole building or are so severe that specialty equipment and tactics are required.
  - o If you do bring in a specialist, be sure they are using HEPA vacuum systems on the job site? If the installation and repair crews are not using HEPA, they should not be providing mold removal service. Is the mold removal crew in compliance with *OSHA Standards – 29 CFR for Respiratory Protection*? Mold removal can be dangerous for persons not fully compliant and well-trained in respirator safety.
  - o To what degree will the inspection identify the *extent* of mold growth? Will destructive techniques be employed during the inspection, such as removing contaminated materials, for further investigation of the extent of damage?
2. Will any of the mold remediation work be warranted? There are many variables to consider and the initial effectiveness of the mold cleanup is only one. Has the cause of the initial mold been remedied and will the customer maintain the home in a way that discourages further mold development?
3. Does current liability insurance cover mold related activities?
4. Are there other reputable contractors providing mold remediation services that you might refer your customers to?

#### **32.3.4. Monitor Radon Levels Within a Building**

Radon monitoring is important because it is potentially a deadly pollutant responsible for thousands of deaths annually in the United States. It is also very unpredictable with reference to location and concentration. Monitoring costs are small and yet the benefits can be life saving. If Radon might be an issue in your geographical area, act accordingly.

Radon is not generally a problem in California. The only reported significant action levels are found in Santa Barbara and Ventura Counties, according to maps provided by the Environmental Protection Agency at <http://www.epa.gov/radon/zonemap/california.htm>.

#### **32.3.5. Provide Wet Cleaning of Lead Contaminated Surfaces**

Cleaning of surfaces that may be lead-contaminated will minimize the possibility of lead exposure to the technician, while providing window repair/replacement, door weatherstripping or woodwork. Once work has been completed, cleaning of the areas will prevent lead and dust exposure of the occupants.

1. If the building pre-dates 1978, it is to be assumed that paints on windows and doors will contain lead, unless testing has verified they do not. Wet cleaning should follow the initial HEPA vacuuming of surfaces required to be disturbed, before work commences and again after work is completed. Approach the handling and cleanup of painted surfaces as though a clearance inspection was required.

2. Prepare a cleaning solution of detergent containing phosphates (dishwasher detergent is suitable) and water. To limit the amount of water applied to surfaces, fill a spray bottle or garden sprayer with the cleaning solution. Apply the cleaning solution lightly to all the painted surfaces of the window, door or woodwork.
3. Using several disposable cleaning cloths or sponges, start at the highest areas and wipe surfaces clean in a downward direction. Make sure all exposed surfaces are washed. Window wells tend to collect a large amount of dusts from the friction caused by window operation. Clean window wells and sill areas thoroughly. Remember that if the window is removed or opened, any existing dust may be carried by wind further into the building.
4. As sashes, stops, casings, etc. are removed, wet and clean any surfaces that were concealed. Besides the cleaning value of this procedure, wetting dry dust makes it heavier and less prone to traveling by wind or air currents.
5. As work is completed, again wet-spray the surfaces of the window or door unit with the cleaning solution and wipe with a clean cloth or sponge in one direction, from the top down. Clean all surfaces in the immediate area (floors, walls) with the same cleaning technique. Repeat this procedure with clean cloths or sponges.
6. Properly discard all cleaning cloths, sponges, debris for the work performed, and personal protection gear such as boot covers and gloves.

### **32.3.6. *Isolate or Remove Sources of Pollutants that Might Affect the Living Areas of the Building***

Most volatile organic compounds (VOCs) that compromise indoor air quality, are either part of the building materials or are brought into the building as a consumer product. Regardless of any physical symptoms of the occupants or sensory indications of VOC levels within the building, every reasonable effort should be made to remove or contain any VOC produced as a result of chemical storage or household supplies. Repackaging or properly storing items like cleaning supplies, laundry products, furniture finishes, aerosols, and insecticides will have the greatest impact on the VOC levels in most homes older than 5 years.

New construction may have a proportionately higher level of VOCs resulting from the building materials of the home. Many plastics, laminated wood, pressed board, vinyl wallpapers, cabinet materials, etc. will off gas organic compounds as they age. The best defense against VOC pollution of the indoor air from new building materials, is to increase the ventilation rate for a period of time. Many builders will actually “cook off” the VOCs from new building materials by raising the temperature in an unoccupied building for an extended period of time.

1. Household chemicals should be kept in airtight containers and out of the living space, if possible. Products that are used often and must remain in the living space should be repackaged if their containment is not airtight. Powdered laundry detergents should be transferred to a dry plastic container, with a screw-on cover. Even this containment will not totally stop the diffusion of chlorine gas into the living space, but will greatly reduce

the diffusion rate. Aerosol containers, furniture polish, shoe polish, air fresheners, and other aromatic household supplies that are destined to be stored indoors should be stored in plastic bins, with snap on lids. Various sizes are commercially available for every storage space. This double containment will slow the diffusion rate to the home air.

2. Chemicals that are stored in the home but are not frequently used should be stored outside of the living space, i.e., the garage or unattached storage. Insecticides, herbicides, construction supplies, PVC weld, acids, industrial cleaners and paints should be kept in plastic storage (to contain spills and dusts) and in a cabinet that is inaccessible to children.
3. Cleaning rags that have been used for chemical application should be discarded. Besides being a major contributor to poor air quality, they also pose a fire hazard and can spontaneously ignite.
4. Where occupants have had some health response due to a new household acquisition such as carpeting or new cabinetry, it may be helpful to accelerate the ventilation with mechanical exhaust or by slightly opening windows.
5. Encapsulation of materials such as particleboard, underlayment for floors, plastic paneling, etc. is usually impractical and should not be expected to resolve poor air quality.

### **32.3.7. *Install Kitchen Exhaust Fan to Remove Pollutants Associated with the Operation of Kitchen Appliances***

1. Pollutants generated in the kitchen (moisture, smoke, and odors) are usually generated at the oven/range area. The range hood area is the ideal location to provide ventilation for the whole kitchen. Most odors and smoke are captured immediately, before they can pollute the zone. A range hood fan or a capture hood connected to an inline fan are two possibilities. Several options exist for fan controllers, allowing for variable flow rates for varying conditions.
2. Select a range hood that is the width of the range top, with a 200 cfm flow rate and a low sone rating of 2 or less. Customers will appreciate the lower sone rating, especially if the fan is to be used more than just intermittently. For a quieter ventilation system, consider an in-line fan and range hood liner. Metal-housed in-line fans are commercially available for this purpose. Select a hood with an easy access to filters and grease trap.
3. Use metal duct for vent connections; a fire code requirement in most areas. Use metal duct for vent connections; a fire code requirement in most areas. Ductwork to exhaust discharge should be as direct as possible and all connections securely fastened according to local codes. Because grease can collect, there needs to be a way to clean the interior, so be sure to consider maintenance accessibility. Remember that in most applications, the exhaust duct will be under *positive* pressure, making duct-sealing even more important.

4. Select a fan controller that provides a range of ventilating options. There may be a need for the fan to operate intermittently at various speeds and possibly continuously at a lower speed, as part of the building ventilation strategy.
5. All kitchen appliances are to be run on ground fault interrupted circuits, including exhaust fans.
6. All exhaust fans must terminate to the outdoors, at a point where exhaust will clear the building. Through the wall exhaust is often the most direct and poses the least amount of ductwork to maintain. Roof mounted exhaust ventilators are also a good point of exhaust discharge.

## **33.0 Installation/Repair Practices—Combustion HVAC, Water Heater, and Appliances**

### **33.1. Scope**

Combustion appliances should be serviced at least every two years for gas and propane (or based on manufacturers recommendation), and once a year for oil. Even electric resistance heating systems should be cleaned annually, to clear dust and debris from the convectors.

Servicing of combustion appliances should include the following:

- Safety inspection (vent, CO, heat exchanger, high temperature limit, flame sensing, combustion, fuel leaks, electrical, zonal pressures)
- Cleaning and lubrication (combustion chamber, burners, heat exchanger, distribution fan, draft inducer)
- Tuning of the combustion process, (fuel pressure, air to fuel ratio, primary and secondary air, CO, and smoke)

In addition, replacement of appliances should be made based on the economics of potential energy savings and maintenance concerns.

Safety concerns for the building occupants, and longevity of the building are foremost during the combustion appliance servicing. The combustion zone should be monitored for fuel leaks and carbon monoxide levels during the servicing, and combustion tuning be conducted under “worst case zone conditions,” as this will reflect the air supply and pressure conditions the tuned appliance will be expected to perform in.

### **33.2. Tools and Materials**

Digital manometer, drill, minor hand tools, kitty litter, disposable towels, hand cleaner, fire extinguisher (10ABC), special brushes for gas appliance cleaning, vacuum cleaner for fine soot.

### **33.3. Procedure**

#### **33.3.1. *Clean Burner Assemblies and Perform Adjustments***

Cleaning of the burners and combustion area should be done after the cleaning of the heat exchanger. As heat exchangers are brushed and cleaned, debris will likely fall into the burner assemblies and combustion chamber. Care must be taken not to damage the fiber combustion chamber during the cleaning process. In all cases, the power source to the appliance must be interrupted while the appliance is being serviced. Prepare the site around the appliance and fuel line. Remove stored items from the immediate vicinity to allow a work area and avoid fuel spill contamination of stored items. Fuel oil has an unpleasant odor and leaks/spills must be cleaned up immediately. Kitty litter or some commercial absorbents with deodorants should be on site, as well as disposable towels, hand cleaner, and fire extinguisher (10ABC).

## 1. Gas fired appliances

- Clean the heat exchangers of furnaces and boilers with brushes designed for the purpose. Brushes have long, flexible handles with varying sized wire brushes for cleaning the narrow passages between plates, tubes and fins, on the combustion side of the exchanger. They are available from heating supply companies. Using a vacuum designed for filtering the fine soot of combustion, vacuum any scale, soot and dirt from the heat exchanger (filters on generic shop vacs are not designed to control the finest soot, which can damage the vacuum motor.) Note: appliances with serpentine heat exchangers are not cleanable with a brush.
- Vacuum all foreign material from the combustion chamber. In many atmospheric gas appliances, this can be done through the opening for the secondary air. Remove burner tubes if necessary to clean scale and rust that may have fallen from the heat exchanger. In-shot gas or power gas burners may need to be removed, for access into the combustion chamber, and to clean and gap the cross light channels.
- On appliances with hot surface ignition, measure the resistance of the cold igniter. Consult with manufacturer specifications to ensure degradation has not occurred.
- Remove the flame sensing rod. Wipe clean with a rag and reinstall.
- Measure the gas pressure at the pressure port of the gas valve and adjust to manufacturer's specification if necessary. Propane at 10.5–11" of water column and natural gas at 3.5" of water column are the usual recommended pressures. On two stage gas valves, consult manufacturer recommendations for the first stage pressure. Check gas pressure of propane with all propane appliances operating. If pressure drops with everything operating, it is an indication of an inadequate second stage propane regulator.
- Adjust the primary air intake on the burner if adjustable, to acquire combustion efficiency at the manufacturer's specification. Performance features will vary for different makes and models, but generally, the oxygen content of the flue gas will be in the 4–8% range, with carbon monoxide at 50 ppm or less. There should never be any soot or smoke production resulting from the combustion of propane or natural gas.
- Measure the flame rectification current to ensure adequate current flow so as to minimize the potential for no-heat calls.
- Confirm the proper operation of the high limit safety switch by interrupting the return air flow while the appliance is operating. A thermometer is used in the supply plenum out of direct line of radiant heat from the heat exchanger to determine the supply air temperature. As the supply air approaches 200°F the safety switch should override the burner.

## 2. Gas and propane water heaters

- Clean the combustion chamber of atmospheric water heaters by closing the main gas valve and disconnecting the burner from the gas line. Carefully remove the burner through the service opening at the bottom of the tank. Brush and vacuum any scale and debris found in the combustion chamber. Brush and clean all orifices in the burner and remove all debris with a vacuum or with pressurized air. Clean the pilot assembly.
- Inspect the flue passage through the water tank. If there is soot or scale present, remove the turbulator and clean the flue pipe that extends through the water tank. Clean and reinstall the turbulator.
- Measure the gas pressure at the pressure port of the gas valve and adjust to manufacturer's specification if necessary. Propane at 10.5–11" of water column and natural gas at 3.5" of water column are the usual recommended pressures. Check gas pressure of propane with all propane appliances operating. If pressure drops with everything operating, it is an indication of an inadequate second stage propane regulator.
- Adjust the primary air intake on the burner, to acquire combustion efficiency at the manufacturer's specification. Performance features will vary for different makes and models, but generally, the oxygen content of the flue gas will be in the 4–8% range, with carbon monoxide at 50 ppm or less. There should never be any soot or smoke production resulting from the combustion of propane or natural gas.
- Adjust the thermostat controlling water temperature to meet the occupant's needs. Some systems are set high to meet greater demands, but temperatures of 120–125°F is usually satisfactory. Avoid higher settings, as this could cause scalding or burning. Perform a vent pressure test and confirm the appliance meets the vent pressures, for existing conditions and record testing results.

### **33.3.2. Clean or Replace Furnace Air Filters**

Air filters for forced air heating and cooling appliances may be located at the return grills in the living space, in the fan cabinet or in the return plenum, close to the fan cabinet. Disposable filters should be replaced a minimum of twice a year, (manufacturer recommends once a month) and more often if warranted by use in areas of high dust or pet hair. An obstructed filter will greatly diminish the performance of the heating/cooling appliance and may cause damage to heat exchangers and freezing up of cooling coils.

1. Replace all disposable filters as needed.
2. Relocate filters in remote areas, to a location where they can easily be serviced by occupants. If appliances are located in an attic or a hard to access area, consider installing a filter at the central return air grill.

3. Clean electrostatic filters by interrupting electrical power to the unit and removing all filtering elements from the fan cabinet. Soak all filter elements in a solution of water and dishwasher detergent. Rinse all components with clean water (pressure rinse if possible). Dry thoroughly before re-installing. Drying the cells can be accomplished by installing the cells in the filter cabinet. With the electronic air cleaner power off, turn the furnace blower to the on position. Allow blower air to dry the electronic air cleaner. Reestablish electrical power supply and run through a heating/cooling cycle. Some electrostatic systems have indicator lights that display proper operation or service problems.
4. Replace media style high efficient filtration per manufacturer recommendations. 1" pleated filters are typically replaced every three months, while the 6" wide media filters are meant to be replaced once a year for normal operating conditions.
5. Replace media style high efficient filtration per manufacturer recommendations. One inch pleated filters are typically replaced every three months, while the 6" wide media filters are meant to be replaced once a year for normal operating conditions.

### **33.3.3. Clean and Lubricate Distribution Fan Motor, Fan Vanes, Inspect/Replace Fan Belt**

An annual cleaning of the fan cabinet, fan motor, air vanes and an inspection of drive belts, should be performed to improve distribution efficiency and provide preventative maintenance.

1. Vacuum dirt and dust from the fan cabinet. This will provide a more healthy air to the home and prevent dust buildup on the fan motor.
2. Remove the blower fan from the cabinet and clean each of the air vanes if necessary. It is important to the balance of the fan that the vanes are cleaned uniformly, to prevent imbalance and bearing wear. Clean and lubricate drive shafts if oilable bearings are present. Lubrication of impregnated bronze bearings will cause premature failure, as dirt will adhere to the assembly.
3. Clean dirt and oil from the fan motor. Dirty/dusty motors will be less able to dissipate heat and will not last as long as motors that are maintained at cooler temperatures. Oilable fan motors usually require a few drops of light machine oil annually. Remove any dirt and hair that may be wound around drive shafts and bearings, and check for free moving armatures.
4. Inspect fan drive belts for signs of wear; either cracks across the belt or fraying along the edges. Replace any belt that shows signs of wear. Set the tension of the drive belt only tight enough so the belt does not slip, (about 1" of deflection with moderate pressure). Too tight belts on motors and blower assemblies with bronze bushings will prematurely cause bearing failure.
5. Inspect pulleys for wear. Friction from the belt will eventually cause wear on the pulley.

### **33.3.4. Clean and Tune Gas Oven/Range Top Burners to Reduce Carbon Monoxide Outputs**

When levels of carbon monoxide are found in ovens and range tops, an attempt to reduce outputs is an important part of assuring a healthy living area. Ovens and ranges typically vent directly into the living space and can threaten the Health of building occupants.

1. Reducing carbon monoxide outputs requires a cleaning of the burner components, at the very least and may require making burner adjustments, (many newer models are factory set and have no burner adjustments).
2. Inspect oven/range for gas leaks with a combustible gas detector and repair all gas leaks found. Inspect the interior for stored items or for devices used to deflect heat, i.e., aluminum foil, and remove prior to starting the oven/range.
3. Regulate gas pressure to manufacturer's specifications. If no specifications are available, set natural gas at 3.5" of water column and propane at 10.5" of water column, with the gas valve open. Check gas pressure of propane with all propane appliances operating. If pressure drops with everything operating, it is an indication of an inadequate second stage propane regulator. This may help during system analysis when CO levels remain high. The performance features of the appliance are very dependent on proper gas pressure.
4. Clean all burner tubes, heads and orifices. Many models can be removed and washed with detergent and water in the sink. Orifices can be brushed clean and the sediment removed from the burner assembly. Completely air dry or use a heat gun or hair dryer to remove all moisture before re-assembling. Some range models have a short mixing tube, where air and gas are mixed. This air tube and any air shutters require cleaning. Even cobwebs in this tube can contribute to the production of carbon monoxide.
5. Adjust the air supply, if an adjustment is present. This must be done with intermittent carbon monoxide tests being conducted to determine the optimum air to fuel mixture. Many newer models lack an adjustable air flow control. Combustion should be quiet and flames should appear precise and steady across the burner, with no ghosting and a minimum of yellow tipping. Above all, the carbon monoxide production has been corrected and is now within acceptable limits.
6. Provide a final carbon monoxide test on the appliance and on the ambient zone, as defined in the Carbon Monoxide Testing Protocol, of the PG&E "Combustion Appliance Safety Test Procedure," and record results.
7. Carbon monoxide production limits are as follows:
  - o 100 ppm as measured in the vent of any vented combustion appliance.
  - o 100 ppm or less, as measured at a distance of 12" above any range burner.
  - o 225 ppm, as measured at the vent of any oven that has been serviced/adjusted by a qualified technician.
  - o 100 ppm, as measured at the vent of any oven that has not been serviced by a qualified technician.

- 10 ppm in any ambient zone of the building, including all living areas, combustion appliance zones, and attached zones
  - The use of any unvented combustion appliance in the living space is not permitted.
8. Provide a final carbon monoxide test on the appliance and on the ambient zone, as defined in the Carbon Monoxide Protocol, and record results.

## 34.0 Installation Practices—Lighting and Appliances

### 34.1. Scope

Incandescent lighting is inefficient by today's standards. Much of the energy used to produce light actually produces heat instead of light. For each Watt of energy used in lighting, 3.4 Btus per hour of heat is produced. This means that a 60 Watt bulb used for one hour, produces 204 Btus of heat. Because florescent bulbs remain cooler and rely on gas, rather than a fragile filament, they last nearly 10 times longer than a comparable incandescent bulb. This—coupled with their efficiency—make lighting upgrades one of the best energy investments for today's homes. Consider also the higher cost of electrical energy, thus most lighting upgrades have a simple payback of one year or less. Modern florescent lighting uses only 30% of the energy to produce the same amount of light and the color rendition has been greatly improved in the last few years. The issues to consider include selection as well as matching utilization to Information that can be gathered on performance characteristics. When compared to Compact Fluorescent Lamps, incandescent light waste more every 15 days than what was paid for the bulb in the first place. It's critical to compare efficiencies before—and after—your involvement.

### 34.2. Tools and Materials

TBD

### 34.3. Procedure

#### 34.3.1. *Install Energy Efficient Lighting Based on Performance Characteristics*

If you are going to be changing out lighting as part of your recommendations, you're going to have to involve the occupants on specific issues around selection.

1. Style  
Aesthetic functions play into the overall satisfaction of your lighting selections. This is a purely subjective decision that should be made by the owners of the building.
2. Vocation  
The goal of each light is a key consideration for occupant satisfaction. Lights in the kitchen are important to work that needs to be performed in the kitchen. This is not the case in a light that illuminates a stairwell.
3. Lumens  
A light that illuminates the front steps generally requires more wattage than a light that is primarily used for reading. This might be an issue for the occupants if someone has fallen recently on the front steps. Using a light meter will help to match the lumens produced by florescent lighting with the incandescent lumens the occupants have found to be acceptable.
4. Quality of light rendition  
If you are going to replace a bathroom light, you might want to pay close attention to the quality of the light rendition—selecting lighting that more closely simulates natural

light. If you are replacing a hall light, this might not be an issue, so you could select a lower-grade bulb that will provide increased efficiencies.

5. If canister lighting is to be mounted in between conditioned and unconditioned space, then the canister lighting should be sealed and Insulated Ceiling rated (IC-rated). Otherwise, air infiltration will reduce the effectiveness of any other air sealing characteristics that have been placed around conditioned space.
6. Recessed lights should always be IC-rated, airtight fixtures.
7. Dimmers should be utilized for incandescent fixtures whenever possible. A special ballast is required for utilizing florescent lights in a fixture that is controlled with a dimmer. Lights should always be IC-rated.
8. Dimmers should be utilized whenever possible. A special ballast is required for lights that can be dimmed.

### **34.3.2.      *Recommend Energy Efficient Appliances***

1. Select appliances that are rated “Energy Star.” This indicates the appliance meets or exceeds federal standards for efficiency, and that it has been independently tested and verified. Typical household appliances that carry the Energy Star label are refrigerators and freezers, air conditioners and heating systems, dishwashers and clothes washers, ventilation fans and lighting fixtures.
2. If you are replacing a fan that has been wired properly to code, then an electrician may not be required to replace the fan. If there is no existing wiring, and the fixture is a new installation, then an electrician may be required. Check with local building codes.
3. Kitchen, bathroom, and outdoor fixtures should always be ground-fault interrupted. This can be as easy as replacing the breaker in the panel box with a ground-fault interrupted breaker switch. Then, everything on that breaker will be ground-fault interrupted. Again, this work must be performed by a licensed electrician. Ground-fault interrupters can also be installed in individual outlets. This may be preferred when only one appliance on a circuit must be protected.
4. Energy Star appliances should be considered for cost and for performance features. New designs can add substantially to energy efficiency characteristics.
5. If you are replacing a fan that has been wired properly to code, then an electrician may not be required to replace the fan. If there is no existing wiring, then an electrician will be required.
6. Kitchen and bathroom fixtures should always be ground-fault interrupted. This can be as easy as replacing the breaker in the panel box with a ground-fault interrupted breaker switch. Then, everything on that breaker will be ground-fault interrupted. Again, this work must be performed by a licensed electrician.
7. Dishwashers sometimes have internal heating elements that consume a surprising amount of power and cannot be turned off. Warn customers to avoid such choices. Dishes do not need to be cleaned in very hot water or dried in high heat.

## 35.0 Installation Practices—Insulation

### 35.1. Scope

Insulation of the building envelope reduces the conductive losses and gains by improving the envelope's resistance to heat flow. This greatly improves comfort, while reducing the energy demand and the size of appliances required for space conditioning. The effectiveness of insulation is greatly dependent on the quality of the installation. Manufacturer's rated R-values refer to the insulation values under "best case" conditions, meaning that the coverage is complete and without voids, the material has been installed to the proper density, and that the insulation is installed with proper and integral air and vapor barriers in place. Any deviation from these installation standards, will adversely affect the performance (R-Value) of the material.

Insulation can be added to an existing building envelope by filling the framing cavities (floor, ceiling and wall) or by installing an additional layer of insulation, usually a rigid board type, adjacent to the frame of the envelope. Insulation should be selected for its ability to completely cover or fill the area of placement and to provide the optimum U-value for the most reasonable cost. It must also be installed in accordance with all fire, electrical and safety regulations. Personal protection equipment is required when installing blown insulation, fiberglass and cellulose or any fiberglass rolls, batts or boards. A fitted respirator and eye protection are required, while gloves and coveralls are recommended.

### 35.2. Tools and Materials

Infrared scanner, blower door test equipment, diagnostic smoke generator, HEPA vacuum cleaner, personal protection equipment including respirators, gloves, eye protection, protective coveralls, and boot covers, heavy mil trash bags.

### 35.3. Procedure

#### 35.3.1. *Insulate Sidewalls With High-Density Cellulose*

Once it has been determined that an existing frame wall can be insulated with high-density cellulose, the opportunities for improved energy efficiency, comfort and sound control are excellent. Properly installed high-density cellulose can provide uniform coverage to all areas, including corners and along the edges of the building frame. In addition, a high-density (3.5 pounds per cubic foot) cellulose is the preferred approach to air sealing the building frame. At this density, a 4" wall cavity will require 1.2 pounds of insulation per square foot, and a 6" wall cavity will require about 1.75 pounds per cubic foot. An injection-type installation (using a hose that is inserted into the wall cavity) is preferred over an injection cone (inserted perpendicular to the wall cavity through the siding/sheathing) because air pressure is maintained and the material is more effectively delivered to the area to be insulated.

1. Inspect all sidewalls with an infrared scanner from inside the building. This will help identify the frame type, fire stops, existing insulation, ductwork, etc. Capturing this image with digital photography can provide a clear roadmap to the insulation installer.

2. Inspect the wall cavities for ductwork, or passages used for air handling. If these cavities are to be insulated, provisions must be made to re-direct the air supply and returns, so they remain operable.
3. Identify any live knob & tube, or aluminum wiring that exists in the wall cavities. It is not permissible to insulate over knob and tube, or aluminum wiring, as this creates a fire hazard. Sub-standard wiring must be replaced before the wall cavity in which it is contained, is insulated.
4. Determine a method for accessing wall cavities. One common approach includes the removal of the exterior siding and then drilling into the sheathing. Occasionally the wall cavities can be accessed from the attic, as with balloon framed construction, or from the interior when siding removal is not possible, as in stucco or brick.
5. Evaluate the lead content of any paint on the siding that will be disturbed. If the paint tests positive for lead—or if no testing has been performed—use lead-safe work practices.
  - Lay out plastic ground covers to collect lead dusts and debris.
  - Use sprayers to wet any painted surface prior to handling. Work while things are wet.
  - HEPA vacuums are used for all cleanups.
  - Personal protection equipment includes respirators, gloves, eye protection, protective coveralls, and boot covers.
  - All dusts, damaged siding, disposable personal protection gear are double-bagged in heavy mil trash bags and properly disposed.
6. Remove siding by unlocking vinyl and aluminum with a zip tool, to reveal the hidden nailing strip at the top of each piece of siding. Gently pull the nails from one course of siding with a thin pry bar. Remove the siding to expose the sheathing.
  - When deciding which length of siding to remove, select a section that runs under the windows. This will minimize the amount of siding required to be removed to provide comprehensive insulation.
  - For wood clapboard siding, gently pry the nails from two courses of siding with a thin flat bar and a nail puller. This will completely loosen one course of siding, which will be removed to reveal the sheathing.
  - Shake siding can be easily removed by scoring the shake at the shadow line near the top of the shake, with a utility knife. Gently lift the shake from the bottom until the shake snaps at the knife score.
  - Drill a 2¼ or 2½3 " hole through the sheathing. If there are no firestops or blockers in the wall system, then an 8- or 10-foot wall cavity can be insulated through just one hole, by injection blowing. When drilling this sheathing, it is important to not force the drill bit past the sheathing, or the electrical wiring in the wall cavity may be damaged by the bit. Through the drilled hole, probe

horizontally with a tape measure or wire probe to determine the location of the next wall stud and the appropriate location for the next hole to be drilled.

7. Assemble the insulation blowing machine and hoses required to reach the wall cavities. Total hose length should be kept under 100 linear feet and laid out in a straight line, to improve air pressure and minimize plugging the hose with insulation material.
  - All hose connections should be airtight to maintain maximum pressure. The primary hose, which is usually 3" in diameter, transitions to the 2 ½" diameter injection hose (and 1 ¼" fill tubes) by way of a smooth metal reducer.
  - The injection hose is usually a 6–8', clear polypropylene hose with enough flexibility to be inserted into the wall and enough rigidity to maintain its shape throughout the application process. Use a thicker walled fill tube for warm weather and a thin wall tube for cold weather.
  - Cutting the tip of the injection hose on a diagonal will help make insertion into the wall and past obstructions easier.
  - During the installation, it is important to provide the right amount of air pressure and material, to prevent the plugging at the reducer. Most insulation blowing machines have air pressure controls and material feed controls, the settings will be dependent on many factors including humidity, the height material must be delivered, physical properties of the insulation and the power of the blower.
  - Provide power to the machine by using properly grounded house current or generator. When using house current, distribute the load to separate circuits for each power cord. If the machine has a powered agitator and two blowers, then three house circuits should be utilized. All power to the insulation machine should be provided through ground fault interrupters, especially during damp or wet conditions.
8. Select cellulose material that is borate-only. It should be treated for control of flame and fire retardancy, and to prevent insect infestation. Borate-treated insulation is less corrosive to metals, than other additives (aluminum sulfate, which can become corrosive) if it becomes wet. Always select Class 1 cellulose that has the UL approval label on each bag.
9. Select cellulose material that is borate-treated for control of flame and fire retardancy, and to prevent insect infestation. Borate-treated insulation is also less corrosive to metal, which is a problem if it becomes wet. Always select Class 1 cellulose that has the UL approval label on each bag.
10. Install cellulose into the wall cavities by inserting the injection hose into the cavity with a twisting motion, until the hose is fully inserted. The hose serves as a probe, and if it cannot be inserted the full height of the wall, an obstruction may warrant another hole be drilled into the wall cavity. The installer operates the blowing machine by way of a power control switch. As the cavity fills from the top down, move the hose slowly from the wall. Once the cavity above the hole has been filled, insert the hose into the cavity

below the hole to complete the fill. Measure the amount of cellulose or count the bags used to fill the first 100 ft<sup>2</sup> of sidewall and compare it to the density standard of 3.5 pounds per cubic foot (1 pound per square foot for a 4" wall cavity). If the amount of material used is less than the standard, increase the air pressure for better compaction. If during the installation, the hose should continue to plug, reduce the amount of material until a balance between the air pressure, material flow and density is reached.

11. Insulate the second floor band joist. This is part of the building envelope and exterior sidewall, yet cannot be accessed from the same holes used to insulate either the first or second floor. This will require removing the exterior siding at the band joist area, or accessing the joist cavity from within the building; either through the first floor ceiling or the second story floor. This area is often the major air leakage point in the building envelope and insulation properly installed, has the added value of major air leakage reduction.
12. Complete the installation by plugging the holes in the sheathing with tapered wooden plugs to fit the hole size and reinstall the siding. Vinyl and aluminum siding should snap lock back in place, once siding has been re-nailed into position.
13. Inspect high-density sidewall insulation by depressurizing the building to 50 Pascal with the blower door, and search for air leakage sites with diagnostic smoke. If a temperature difference exists to the outside, perform an infrared inspection after the house has been depressurized with the blower door.
14. Use HEPA vacuum cleaners for cleanup.

### **35.3.2.      *Insulate Attics and Roof Systems***

Several options exist when deciding what techniques and materials should be used to insulate an attic or roof system. The determining factors are accessibility and available space for insulation. Where attics are accessible and when space permits, a blanket of blown cellulose is an effective and inexpensive way of filling unusually sized spaces and providing even coverage. When a floored attic exists, high-density cellulose will provide some air sealing capabilities, while also providing a uniform thermal boundary. Normally in attics, ventilation is installed to relieve heat and moisture buildup in the attic. In cooling climates, radiant barriers installed over the insulation can be very effective at reducing heat transfer from the attic to the conditioned space. Radiant barriers are usually only effective in the warmest of climates.

#### ***Attics***

1. Install attic vents in accordance with ventilation requirements. If excessive summer heat buildup is expected, ventilation should equal 1 ft<sup>2</sup> of ventilation for each 300 ft<sup>2</sup> of attic space. One half of the ventilation should be installed low in the attic, with one half of the open area being higher in the attic. This will encourage airflow. Installing ventilation in opposite gable ends encourages cross ventilation. Use screens to keep birds, bats and insects from entering the attic through these vents.

2. Air seal any bypasses from the conditioned space below, to the attic floor. Seal any electrical, plumbing and framing penetrations. Urethane foam works well for areas that are not associated with any heat sources.
3. Air seal any ductwork found in the attic. Seal leakage of plenums, distribution boxes, register boots and duct connects with fasteners and latex-based mastic. If flex ducts are to be suspended above the installed insulation, install duct hangers every 6', minimum.
4. Poor wiring must be replaced before the attic is insulated. Do not insulate over knob and tube, or aluminum wiring, as this creates a fire hazard.
5. Baffle around heat sources, forming a metal barrier between the insulation and heat sources. Recessed light fixtures, combustion vent pipes and electrical appliances require a code-specified clearance be maintained. Electrical boxes must be properly covered and should be marked in some way for future identification. Using wide fiberglass insulation batts, baffle around the attic access hatch, to form an insulated barrier that will keep loose fill insulation away from the access.
6. Insulate the attic hatch or access with 4–6" of rigid foam board, secured to the attic side of the hatch door. The attic access should be properly weatherstripped to prevent air leakage.
7. Secure depth markers to the attic floor joists every so often throughout the attic. The installer will gauge the depth of the delivered material by these markers.
8. Install wind baffles around the eaves, wherever ventilation will be provided. The baffle is designed to direct ventilation over the insulation nearest the sidewall. Wind blowing through the insulation will reduce its effective R-value.
9. Use an insulation blowing machine to reach the distant attic areas. The primary hose is used for installing cellulose in an attic without a floor. During the installation, it is important to prevent creating unnecessary amounts of dust in the attic. Air pressure required to freely move the insulation through the hose should not be exceeded. The material feed should be in the full open position.
10. Operate the blowing machine and install cellulose insulation to the desired depth, starting in the areas furthest from the access and working toward the escape area. Maintain a level uniform application, using the markers as guides to depth. The finished insulation depth should equal 12" where room permits and should cover all floor joists and framing materials.
11. Attic knee-walls are usually constructed with no sheathing on the attic side of the frame. Simply hanging fiberglass batts in the knee-wall frame is an ineffective insulation technique because air moving through the attic will move through the insulation batts and dramatically reduce the R-Value of the material. If fiberglass batts are used to insulate knee-walls, encase the insulation batts within the wall cavity by placing a rigid sheathing or insulation board over the insulation and the wall frame, on the attic side of the wall. Alternatives to using fiberglass batts include spraying the wall frame and cavities with 2 part urethane foam, installing rigid insulation board on the attic side of

the wall, or installing blown fiberglass or cellulose (high density) into a wall cavity that has been closed with sheathing on the attic side of the wall.

### **Roof systems**

1. Insulating vaulted ceilings requires designing a very effective air barrier, vapor barrier, ventilation and R-value, all in a very limited space. High tech insulation materials have good application in flat roof and vaulted ceiling insulation, because they have a high R-value per inch and a good air/vapor barrier.
2. Roof systems or vaulted ceilings can be insulated using a ventilation channel (2") between the insulation and the roof deck or by filling the rafter/truss full of insulation and not incorporating a ventilation system. The ventilated roof deck requires a clear opening from the eaves or rafter end to a ventilated ridge. Most shingle manufacturers require a ventilated roof deck, to honor the manufacturer's warranty on roofing materials. If there is a possibility of condensation forming, (either by air leakage into the roof system or by marginal amounts of insulation, causing dewpoint to form within the roof system) then a ventilated system is usually recommended. An airtight ceiling is critical for proper performance of this roof system design.
3. Seal the spaces between rafter ends *at the eaves*. Using a rigid material like insulation board, plywood, heavy cardboard, etc. Block off all of the openings, except for a 2" space, directly below the roof deck. This will remain open for ventilation. The blockers should be in alignment with the exterior vertical wall of the house, to allow rafter insulation to extend over the exterior wall plate. Fit the blockers, secure them with fasteners and seal them in place with a durable caulking compound. This configuration is important, as it prevents "wind washing" (reduced R-Value) of the insulation.
4. Provide ventilation at the top of the 2" air space between the insulation and the roof deck. This is usually done with a ridge vent or with rafters leading to an attic zone, that can provide the necessary ventilation dynamics; air moving from outdoors back to outdoors, through the attic.
5. Install as much insulation between rafters, while still maintaining a 2" open channel between the insulation and the roof deck. Installed R-values should be part of a design to prevent dew point formation within the system, and to resist the solar gains typical to sloped and dark roof surfaces. If the rafter is 8", the cavity should be insulated with 6 inches, if the rafter is 12 inches, the insulation should be 10". A vaulted truss system should have a minimum of 10". Fiberglass insulation should be foil or kraft faced, with the face stapled to the room side of the rafters.
6. Whenever possible, supplement existing insulation by installing a rigid board insulation (polystyrene, polyisocyanurate, urethane) on the living space side of the rafters. This provides insulation of the building frame, as well as the cavity, and can be an effective vapor barrier. If the insulation is foil-faced, some radiant values for this insulation may be realized. Covering rigid insulation board with a fire rated material (drywall) is

required. If the roof system is not ventilated, rigid insulation can be placed directly beneath the roof deck, on the upper side of the rafter.

7. Skylight shafts and dormers have framed vertical walls that should be insulated in the same manner as the exterior house walls. High density cellulose can be blown into each frame cavity, by drilling a hole through the interior finish and injecting insulation through the hole. Because dormers and skylight shafts have short walls, a 1" hole will allow for a high density installation, provided the material flow and air pressure of the blowing machine are properly regulated (low material volume, high air pressure). Holes drilled through interior surfaces are to be plugged with tapered wood plugs, recessed ¼" and then finished with drywall compound and interior paint.
8. The finished ceiling of the roof system should be air sealed, primed and painted. In most cases, the paint and primer serves as an effective vapor barrier. If the ceiling is to be finished with a material such as tongue and groove boards, or some other material that is not an effective air barrier, then an air barrier should be installed to the under side of the rafter *prior to the installation of the finished material*. Plywood, OSB, or the recommended rigid insulation board will provide an effective air barrier.

### **35.3.3. Insulate Floor and Foundation Areas**

Establishing a thermal boundary around the foundation wall (or around the slab on grade) provides for "earth-coupling" of the building that can have energy and comfort advantages. When insulated to the proper depth below grade, an earth-coupled foundation can provide a winter heat source to the building and a summer heat sink that helps moderate extremes in outdoor air temperature. In cold climates, where frost is expected, the foundation insulation should extend from the top of the foundation wall to below the typical frost depths. In climates without frost, the foundation insulation should extend from the top of the foundation, to 2' below the grade level.

Extruded polystyrene is an ideal foundation insulation because it can be placed on either the interior surface of the foundation or the exterior surface - and this product is not affected by water or moisture. However, if this material is used on the exterior of the foundation, it requires covering to protect it from the sun's ultra-violet light.

Framed floor insulation is usually installed between the joists of floors over unconditioned spaces, i.e., basements, garages and crawl spaces. Rigid foam insulation can be used, but fiberglass batts are the most commonly used insulation material. A supporting system of wire mesh fastened to the bottom of the floor joists is used to keep the fiberglass batts in place. This application does not take advantage of the principles of earth-coupling, but is often used because it is inexpensive and easy to install.

#### **Foundations**

1. Air seal the foundation connection to the sill plate, and any other obvious air leakage paths through the foundation/crawl space wall.

2. Insulate the interior or exterior of the foundation wall with 2" of extruded polystyrene (R-10). Use adhesive designed for polystyrene (Dow PL-200) to affix the insulation directly to the masonry foundation. When insulating the exterior of a slab on grade, adhesive is not required, as the backfilled earth prevents any movement of the installed insulation. If exterior insulation should be finished with a covering to protect it from ultra-violet light, consider a mason's lath and mortar finish.
3. If the region is termite prone, select another method of insulating the above grade foundation; either insulating the interior of the foundation wall or insulating the floor between the crawl space and conditioned living space. This will leave the exterior of the building exposed for termite inspection.
4. Cover earth floors of a crawl space with a heavy mil polyethylene tarp, weighted in place and overlapped at the seams, to prohibit the evaporation of moisture from the earth to the crawl space area.
5. Install manually operable ventilators in the foundation wall of the crawl space. These ventilators should remain in the closed position unless ventilation can be provided with dry outside air. Outdoor air at 80°F and 40% relative humidity will condense on a cool building surface of about 55°F. For warmer temperatures or higher relative humidity, leave vents in the closed position.

### ***Framed floors***

1. Air seal any bypasses in the floor between the conditioned space and the basement/crawl space area, i.e., plumbing, duct, electrical, or framing.
2. Insulate all ductwork and water lines within the crawl space area. If freezing temperatures are anticipated, drain traps should be insulated/isolated to prevent freezing.
3. Install heavy mil polyethylene sheeting over any earthen floor of a crawl space to prevent the evaporation of moisture from the earth to the crawl space area. Overlap any seams and weight the sheeting in place with stones, gravel or other inorganic material.
4. Install insulation to the full depth of the floor joists; 6"-fiberglass batts for a 6"-floor joist, 10"-batt for a 10"-joist. When installing faced fiberglass batts, the facing should be positioned to the conditioned floor of the building. Friction fit the batts to temporarily hold them in place
5. Support the insulation with rolls of 2"-wire mesh, run perpendicular to the floor joists and stapled in place to the bottom of the floor joist. This will give good support to the settled floor insulation.
6. If the crawl space area accumulates moisture that requires ventilation, ventilate the crawl space with manually operable vents that can be opened. In these situations, provide ventilation only when the outdoor air is dry and will not condense within the crawl space.

7. Floors of bonus rooms (living space above garages) benefit greatly from the installation of high density cellulose, even if the floor has been previously insulated with fiberglass batts. The high density cellulose helps to provide an airtight barrier between the garage—which can be the source of carbon monoxide, volatile organic compounds—and the living space, which is often used as a bedroom. High density cellulose in this floor area greatly reduces airflow through the building frame, which almost always exists in this type of construction. Installation can be accomplished with an injection hose, through the garage ceiling. Density should be in the range of 3.5 pounds per cubic foot, or about 2.25 pounds per square foot in an 8" floor joist. All penetrations in the garage ceiling must be plugged and sealed, as this ceiling serves as a fire barrier between the garage and the living space.

#### **35.3.4. Determine the Requirements and Location for Vapor Barrier Placement, With Installed Insulation**

Vapor barriers are intended to restrict the movement of moisture into the insulation and building frame. In most climates the vapor barrier belongs on the conditioned side of the envelope, to deter household moisture from migrating into the building envelope. In climates where the outdoor air is humid, the barrier would best be located on the exterior of the wall frame. In the case of ventilated attics, the vapor barrier belongs on the conditioned side of the ceiling. Where floors are insulated, the vapor barrier belongs on the conditioned side of the floor. When effective vapor barriers are in place, any moisture that may accumulate within the building envelope will be required to dry to the side of the envelope that has no barrier. An integral vapor barrier is less of a concern in areas where the year around climate is quite dry, and when indoor moisture is properly controlled.

1. Vapor barriers are best installed at the time of construction or remodeling. Establishing a vapor barrier in an existing building—when one does not exist—may have varying levels of success, because it is difficult to maintain the continuity of the barrier.
2. Vapor barriers can be constructed of an impermeable construction material, such as a foil faced insulation, polystyrene insulation board, or impermeable paint on the surface of an airtight drywall system. Most building materials are given a perm rating by ASHRAE and most vapor barriers have a rating of less than 1 perm. Vapor barriers are only effective with envelopes that are well air sealed. Airflow is responsible for the transfer of most moisture into the envelope.
3. NOTE: A vapor barrier serves a different purpose from a capillary break. Controlling moisture migration into the building frame—from wherever the frame comes into contact with the foundation or the earth—requires an interruption (capillary break) in the wicking action of the earth to masonry to wood. This is usually a material such as “Water and Ice Shield,” a water repellent mat or “Sill Seal” (a water repellent soft closed cell foam that is installed during construction, between the masonry and wood contact points).

4. Air seal the envelope to prevent moisture movement from the interior to the exterior. This is especially important in areas of high moisture, such as kitchens, bath and laundry areas. Plumbing and electrical penetrations into floors, walls and ceilings should be sealed with approved materials and techniques. Ducts that extend outside of the living space may serve as a route of moisture migration and must be air sealed.
5. Install vapor barriers in areas of potentially high moisture generation, i.e., kitchens bath and laundry areas. Where the existing interior finish is drywall or similar material, low perm paint, as the primer or finish, can be an effective vapor barrier. Where the interior finish has not been installed, an airtight drywall system, painted with a low perm paint, is recommended.

## 36.0 Installation Practices—Air Distribution Systems

### 36.1. Scope

Proper design, installation, and repair of heating and cooling distribution systems is critical to “whole house” performance. Heating and cooling appliance efficiencies are totally dependent on the distribution system, as is air balancing and air quality of the living space. Many homes lack sufficient return air supply, and many systems are often plagued with air leakage that introduces extreme air temperatures and pollutants into the conditioned space. This is especially true when the leaks from supply and return distribution are located in zones outside of the living area as in crawl spaces and attics.

### 36.2. Tools and Materials

Duct insulation, blower door, diagnostic smoke generator, self-tapping metal screws, duct blaster, True Flow, pressure pan, digital gauge.

### 36.3. Procedure

#### 36.3.1. *Distribution System Repair—Redesign Criteria*

A properly designed distribution system removes air from the living space, conditions the air, and then re-introduces it to the living space, without changing the pressure of the living space. When supply system leaks exist outside of the living space, the conditioned areas will likely experience a negative pressure. When return system leaks exist outside of the living space, a positive pressure will likely result. Both situations reduce the efficiency of the mechanical systems.

1. Distribution system leakage is not to exceed 6% of the total capacity of the air handler. This requires measuring the airflow rate of the system by way of a flow plate or by determining the fan flow curve for the pressures measured in the fan cabinet. For example: A distribution system measuring 1600 cfm is required to have no more than 60 cfm or 6%—whichever is less.
2. Pressures created within any area of the living space are not to exceed 3 Pascal (positive or negative) with reference to the outdoors *when air handlers are operating*. This requires measuring the base reference pressure of each conditioned zone prior to activating the air handler - and again once the air handler is operating. Pressures should be measured with the house closed up in “worst-case” mode, and with doors to each zone of the living space both opened and closed.
3. Radiant and convective losses from appliance plenums and ductwork located in unconditioned areas are to be minimized with duct insulation. Properly installed duct insulation will minimize both heating and cooling losses between the appliance and the living space, while also preventing condensation on both the exterior and interior of ductwork.
4. Duct insulation should have a minimum resistance value of R-5. If the duct is in the unconditioned space, then it should be at least R-8.

5. Duct insulation should be installed on any plenum or ductwork (supply and return) where the temperature difference between the zone and the conditioned air is greater than 15°F it. Both the supply and return ducts need to be insulated.
6. The temperature rise or temperature drop of air moving across the heating/cooling appliance has to be within the specifications recommended by the manufacturer. This indicates that the properly designed volume of air is moving from the return system, across the exchanger and into the supply side of the distribution system, providing optimum efficiency. Manufacturer's recommendations are usually in the range of 400 cfm per ton (12,000 Btu/hour) of cooling design, and enough air across heat exchanger of a heating appliance to maintain a steady supply airflow temperature of about 40–70°F above the return air temperature.
7. Insufficient return air in an air conditioning system can result in the icing of the evaporator coil, which has the impact of further reducing airflow across the coil. This will reduce the life of the compressor by returning liquid refrigerant to the compressor, and washing the oil out of the compressor too.
8. Insufficient return air in a heating system will result in the supply air temperature climbing continuously through the cycle until high limit shut-off temperature is reached and short cycling of the appliance occurs.

### **Repair**

1. *Restricted or dirty evaporator coil or heat exchanger.* Heat exchangers and evaporator coils require cleaning every 2 or 3 years, depending on the conditions. The air passages through these coils can become obstructed by dust, insulation fibers and animal hair. Openings in the fan cabinet or return plenum are notorious sources of dust and debris, especially when the system is located in the crawl space. You should access the evaporator coil and carefully clean dust, hair and fibers from the coil. Spray evaporator coil with cleaning solution and rinse. Straighten any bent aluminum fins found on the coil.
2. *Insufficient or restricted return air system.* This condition may be identified by a banging noise from the return plenum at startup of the air distribution fan, or by high negative pressures in the return plenum. (Be suspicious of pressures above -100 Pascal.) Be sure that all return registers in the building are free from obstruction and that the air filters are clean or removed before measuring pressures. Ideally, the return side pressures should be no higher in negative pressure than what the supply side is in positive pressure. You'll have to assess the need for additional return registers to improve convective cycling within the living spaces, and to improve comfort for occupants.
3. *Insufficient or restricted supply air system.* Typical home design usually incorporates enough supply ducting, but restrictions can be caused by collapsed or restricted trunks or ducts. Flex duct can be restricted when stepped on, or when weighed down with additional insulation. Long runs of flex duct can be expected to create resistance to airflow. Ductwork less than 6" in diameter can also be expected to pose some restriction to flow. Make sure all balancing dampers in the ductwork have been opened for your

duct evaluation. The ideal supply side pressure depends on the ductwork design, but is usually in the range of positive 25 to 50 Pascal. The comfort of the occupants is a determining factor, so the air velocity from registers should be efficient and comfortable. Supply pressures are also very dependent on the performance of the return air system. If the return side is starved for air, the supply side will exhibit a reduced positive pressure. Correction of this scenario will require improving the return design. If the return system does not extend into a conditioned zone, then introducing a return air system into this area will encourage convective cycling within the zone/rooms and occupant comfort should be improved.

4. *Insufficient fan flow or fan size.* Increasing fan outputs can improve circulation of conditioned air and is especially important when moving cooling air. If the temperature of the second floor is an issue with occupants, you may have to increase fan flow. The heavier nature of cooler air requires more supply duct pressure (a suggested minimum of 50 Pascals) to move it vertically to a 2nd floor. Many systems have multi speed fans that require changing electrical connections or pulleys that can be adjusted for increased fan revolutions. Do not increase fan speeds if high negative pressures already exist in the return air system. This will further increase the negative pressures in the system.
5. *Restricted duct size and design.* It's important to determine the appropriateness of the duct sizing. Fifty to sixty percent of existing duct systems would be better replaced than sealed. Airflow for return and/or supply systems can be improved by increasing the size of the ductwork and removing sharp turns and angles of the distribution system. This is especially true with air conditioning systems and increasing the size of ducts may be easier than installing additional duct runs.
6. *Filtration systems.* When designing a system with a MERV 6 or higher filter, the system should be sized for the increase in static pressure using the same filter depth or increase in-line space. The increase in in-line space 2–12" allows a higher MERV efficiency to be used while keeping the static pressure of the system below 0.08". New filtration technologies are also being developed to overcome the static pressure issues. In fact, a home owner can now purchase a MERV 13 filter with an initial static pressure of 0.12" w.g @ 300 fpm (still too high) or .28" w.g. @ 500 fpm (way too high). Most residential systems are not designed properly, and have approximately 400 fpm or greater at the return. The trick here is to include inline space for the filtration system. For example , you need about 18" of space to use the MERV 13-24 x 24 x 11 1/2" filter. As far as the MERV 9-11 filters go, the key here is to use a 4" filter instead of the 1" or 2" filter typically used in residential systems. A 4" MERV 11 filter has an initial pressure drop of .14" w.g. @ 300 fpm compared to a 2" MERV 4 polyester panel filter with a .25" w.g. @ 300 fpm or 1" MERV 6 .30" w.g @ 300 fpm.

### **36.3.2. Identify and Correct Duct Leakage and Conditioned Air Leakage Into Unheated Crawl Spaces and Attic Areas**

Identifying leaks from ducts—and from the building envelope—is best accomplished by first performing a visual inspection of unconditioned zones and ductwork within these zones, and then repairing the obvious leaks. This air sealing will likely assist in additional diagnostics to reveal more subtle or hidden leakage.

1. A blower door can be used to depressurize the living space and ductwork—causing diagnostic smoke to identify leakage sites—when applied from crawl space and attic areas.
2. Secure the metal ductwork with self-tapping metal screws at takeoffs and at each connection to prevent separation. Three screws per connection is recommended. When flex duct is used, the inner lining must be securely connected to the takeoffs and boot connections with nylon strapping or metal clamps.
3. Secure a suspended duct system with hangers, strapping, or fasteners to prevent movement. Ductwork should be secured every 6' to 8' (4' support for flex duct). When suspending flex duct, supports must prevent the duct from sagging under its own weight.
4. Seal all fan cabinet doors with gasket material, or metal tape, if leakage is identified.
5. Seal the supply and return plenums to the combustion appliance with quality metal tape or mastic. When applied to a clean surface, this will provide a lasting seal that can also be removed for maintenance and replacement. *Duct tape should not be used on ductwork, as it has proven to be an unreliable sealing material.*
6. Seal any leaks in the fan cabinet with latex based duct mastic. Where leakage sites are larger than 3/16" across, use mastic with fiber mesh tape. The fiber tape will help bridge most gaps.
7. Seal each duct connect—from the plenum to the boot connect—with latex based duct mastic. Metal ducts require the application of mastic to each seam, including those found in metal adjustable elbows. Flex duct will require sealing at the plenum connects and at the boot connects. Use latex based mastic to seal the secured duct connection. It is likely that these are the only two leakage sites associated with flex duct.
8. Remove supply and return register covers, and seal any gaps between the register boot and the floor, wall or ceiling. Where the building frame is being used as part of the distribution system, inspect the inside for blockers used to seal the stud or joist cavities from needless interaction with other areas of the building frame.
9. Perform a duct leakage test once all sealing work has been completed and the mastic has had enough time to properly set. The mastic will not be properly dried for several hours, but low pressure duct testing (25 Pascal) can be conducted while it is drying. If air sealing goals have not been met, use pressure pan testing of individual duct runs. Leaks are most likely located in duct runs with the greatest pressure drops.

### **36.3.3. Identify and Install Various Duct and Pipe Insulations**

The insulating of ductwork and water pipes becomes more important as the temperatures in the duct zones become more severe. For example, an attic of 145°F containing AC ductwork at 75°F will introduce 70 Btu/hour/square foot to the temperature of the conditioned air. If the ductwork is insulated with R-8, the heat gain to the conditioned air within the ductwork is reduced from 70 to 9 Btu/hour/square foot of exposed ductwork. For the average supply with 300 ft<sup>2</sup> of surface area, this could translate to well over a ton of cooling load.

Hot and cold water lines that are located in crawlspaces should also be insulated to avoid the potential for condensation on cold water lines, and radiant energy losses from hot water lines. All duct repairs and sealing must be completed before duct insulation is installed.

1. Ductwork should be insulated with a minimum R-8 insulation. Fiberglass duct wrap or flexible foam wraps are recommended. Many types of flex duct are constructed with an insulation material included and they typically do not require additional insulation. When metal ductwork is used, an insulated sleeve of flex duct is an effective insulation technique.
2. Insulation must be secured with wire, banding or fasteners to hold it in place.
3. Plenums requiring insulation can be wrapped with fiberglass duct insulation or rigid insulation board. When insulating the plenums of high-temperature (negative pressure) vented appliances, maintain a reasonable clearance of 6" between the vent pipe and the plenum insulation.
4. Domestic water and hydronic heating pipes require insulation wherever they are located in a zone outside of the living space or when they are routinely subject to ambient temperatures 15°F different from the surface temperature of the pipe. For example, when a domestic hot water pipe of 120°F is located in a zone that is typically 60°F, seasonally, this water pipe should be insulated. This rule is applicable to cold water lines and hydronic return lines, as well as hot water lines and hydronic supply lines.

### **36.3.4. Cooling Distribution System Design Considerations Including Convective Loop Impacts**

Cold air distribution systems must account for the difficulties in moving cool air (AC) to the second floor. Denser cold air does not move through ducts as easily, especially if the system was designed for warm air. This presents challenges in duct design when central air conditioning is being considered as an add-on to an existing heating distribution system. The system may be designed to move warm air to the second floor, but cool air requires additional fan flow/pressure.

1. *Comfort issues:* Evaluate the distribution system in context of comfort issues or complaints of the occupants. This will help identify areas for improvement, and may provide clues to specific design problems.

2. *Appliance location:* Cooling loads are generally greater for the upper levels of the living space, so when the cooling appliance and distribution is located in the attic, a relatively short distribution system will use gravity to move cold air from the ceiling to lower regions of the building will benefit the distribution efficiency. Where the cooling appliance is located in a lower region of the house and cooling air must be delivered to higher levels, you should consider larger ducts, greater duct pressures and higher fan speeds to improve performance.
3. *The evaporator coil* can produce greater resistance to airflow than a heat exchanger of a furnace. Larger fans or greater fan speeds should be considered when central air conditioning fails to provide cooling comfort.
4. *Air filter systems* can also produce resistance to flow, especially when filters are dirty. The filters should be located in the return side of the distribution system where they are easily accessed for cleaning/replacement.
5. *Convective cycling:* The placement of the supply and return registers is an important part of establishing good convective cycling within the living space. Returns should have at least the same capacity for airflow as the supply side of the distribution. Air conditioning returns should be placed where they can collect the warmer air of the living space - which because of stratification is located nearer the ceiling. Supply registers placed high in the building will also drop cold air to the living area. If supplies are located closer to the floor, cold air will tend to stratify at this level, and if returns are located lower in the zone, the warmer air of the zone will remain in the upper portion of the zone and the returns will recycle air that is already conditioned. Where doorways, partitions or bulkheads disrupt convective cycling, returns should be installed in areas that have been identified as having comfort problems.

### **36.3.5.      *Maintaining Humidifiers and Condensate Pans in Central Conditioning Appliances***

Humidifiers and condensation from air conditioning are two sources of moisture found within the HVAC appliance. In both cases, moisture can leak onto the heat exchanger and cause premature deterioration. HVAC appliances containing humidifiers or coils should be inspected to assure damage has not occurred to the heat exchanger or any other component of the HVAC appliance.

1. Inspect the condensate pan and drain system located beneath the evaporator coil. If leaks are evident, make necessary repairs. Clean condensate systems with an anti-bacterial solution and rinse clean. Check the drain line and p-trap, and the drain termination location too.
2. When humidifiers are located in the supply plenum, verify that it performs properly and that humidity has not leaked onto the heat exchanger. If leakage or corrosion is evident, or if it is determined that the humidifier is not functional, then it should be removed from the supply plenum and the plenum should be properly sealed. Humidification should only be used in response to hygrometers indicating the living space is

uncomfortably dry. In this case, a portable humidifier is easier to service and will not pose damage to the heat exchanger.

3. Humidifiers located in the central distribution system that are to remain in service, should be cleaned with an antibacterial solution, to prevent mold and bacteria growth in the system.



## 37.0 Installation Practices—Cooling Systems

### 37.1. Scope

Research conducted on installed air conditioning systems indicate that over half of all systems are not properly charged, meaning they operate with less efficiency than designed. Often cooling systems are installed during a time of year when outdoor air temperatures do not permit for an accurate evaluation of refrigerant charge. Additionally, installed systems are rarely checked for refrigerant charge when they receive maintenance/cleaning.

Air conditioning systems should be properly sized for the living space being conditioned, at the appropriate design temperature for the building location. Manual J residential load calculations and Manual D duct sizing / efficiency calculations are used to make equipment size determinations. Cooling loads comprise both the sensible and latent energy, a function of air temperature and humidity levels. The energy efficiency rating reflects the Btus.

The tables and procedures outlined here are designed for use with refrigerant R-22 systems. Systems using other types of refrigerants will require other appropriate charging and airflow charts. NOTE: You may need an EPA Refrigerant license to perform some of these steps.

### 37.2. Tools and Materials

Calibrated wet-bulb and dry-bulb thermometers, refrigerant pressure gauges, Psychrometric pressure temperature chart, pencil.

### 37.3. Procedure

#### **37.3.1. *Instrument Attachment and House Configuration: Superheat and Subcooling Evaluation***

Air conditioning evaluation requires the outdoor air temperature (dry bulb) be above 55°F.

1. Establish an environment with a return air dry bulb temperature above 70°F, during the cooling evaluation.
2. Connect the refrigerant pressure gauge to the service access fitting before turning the cooling system on. This will help to avoid the loss of refrigerant.
3. Ensure that all cabinet panels are in place and air cannot by-pass around the condenser and evaporator coil.
4. Set the house in cooling mode, with exterior doors and windows closed and the thermostat set 10°F below the interior air temperature.
5. For appliances with fixed orifice metering devices, connect a thermocouple to the suction line near the service access fitting. The thermocouple must be in direct contact with the refrigerant tubing and insulated from the ambient temperature and radiant heat. For TXV evaporators, attach this thermocouple to the suction line at the TXV sensing bulb.

6. Connect a thermocouple to the liquid line near the service access fitting. This thermocouple will be used to calculate subcooling; an indication of the amount of refrigerant in the system. The thermocouple must be in direct contact with the refrigerant tubing and insulated from the ambient temperature and radiant heat.
7. Connect a thermocouple convenient to measure the outdoor air entering the condenser coil. Avoid placing thermocouple in direct sunlight.
8. Connect a thermocouple convenient to measure outdoor air exiting the condenser coil. Avoid placing thermocouple in direct sunlight.
9. Before recording system data, place a wet bulb thermometer in the indoor return air stream, before the evaporator coil and let stabilize.
10. Place a dry bulb thermometer in the indoor return air stream, before the evaporator coil.
11. Place a dry bulb thermocouple in the indoor supply air stream, as air exits the evaporator coil.

### **37.3.2. Data Collection for Air Conditioning Systems**

1. Operate the system for about 15 minutes, until the temperatures and pressures have stabilized (steady state). Collect the following information concerning pressures, temperatures and electrical demands of the system.

Suction Pressure	(PSI)
Head Pressure	(PSI)
Suction Line (Dry bulb) Temp	(°F)
Liquid Line (Dry bulb) Temp	(°F)
Outdoor (dry bulb) Temp Entering Condenser	(°F)
Outdoor (dry bulb) Leaving Condenser	(°F)
Indoor (wet bulb) Entering Evaporator Coil	(°F)
Indoor (dry bulb) Entering Evaporator Coil	(°F)
Indoor (dry bulb) leaving evaporator coil	(°F)
Condenser Voltage	Volt
Condenser Amperage	Amp
Evaporator Fan Voltage	Volt
Evaporator Fan Amperage	Amp

2. Once the indoor return air (wet bulb) temperature has been taken, place the wet bulb thermometer in the supply air stream and record the web bulb temperature of the air exiting the evaporator coil, when the thermometer has stabilized.
3. After data has been collected, turn system off before disconnecting gauge manifold, to avoid refrigerant leakage.
4. From the pressure temperature chart, determine the saturation temperature of the refrigerant in both suction and liquid lines.

### 37.3.3. Superheat Charging Calculations: Non-TXV Cooling Systems

Both fixed orifice (piston) and capillary tube type metering devices can be evaluated using this method. If airflow is altered after performing these calculations, by way of duct design or air sealing, the superheat should be recalculated to ensure it is still within accepted range.

1. Calculate the actual superheat the system is operating under:
  - Suction Line Temp (dry bulb) – Evaporator Saturation Temp = Actual Superheat
  - If the target superheat value is a dash (–), then the value will be less than 5°, and the system fails the recommended refrigerant charge criteria. The system may be in potential danger of flooding the compressor. This situation may be caused by overcharged system, hot outdoor temperatures, or by a dry and cool indoor environment. Increasing the indoor temperatures and humidity may bring the environment within range of Table 1.
2. Calculate the difference between actual and target superheat.
  - Actual Superheat – Target Superheat = Variance
  - If the superheat variance is + or – 5°F, the system *passes* the recommended refrigerant charge criteria.
  - If the superheat variance is greater than 5°F, then the system *fails* the recommended refrigerant charge criteria. For every 1 degree of variance from the target superheat, the system charge will be approximately 1.1 oz. *less* than factory recommended charge—by weight. On a new system, this may indicate an undercharged system. Several common problems may cause this variance: undersized metering piston, restriction in a line or filter dryer.
  - If the superheat variance is less than 5°F, then the system *fails* the recommended refrigerant charge criteria. For every 1 degree of variance from the target superheat, the system charge will be approximately 1.1 oz. *Over* the factory recommended charge, by weight. Several common problems may cause this condition: oversized metering piston, low evaporator airflow, obstructed airflow over the condenser coil.
3. If it has been determined that the reason for failure of system charge criteria is over or under charge, the percent of variance can be determined as follows:
  - Refrigerant Variance = 1.1 X Variance from Target Superheat (Oz.)
  - System Charge Variance = refrigerant variance/ Factory charge (%)
4. Calculate the system subcooling. This value will aid in determining if there is a refrigerant charge problem or possible alternative problem in the event the system fails the recommended refrigerant charge criteria with a fixed orifice type meter device.
  - Condenser Saturation Temp – Liquid Line Temp (dry bulb) = Subcool Temp

### **37.3.4. Subcooling Charging Calculations: TXV Cooling Systems**

A thermo expansion valve (TXV) is an adjustable orifice that seeks to maintain a constant superheat. Manufacturers specify a valve to maintain a specific superheat that will fall in a range of 12–15°F. Check with the manufacturer to determine actual values for a valve being used. For this reason, subcooling is the method for determining proper charge. Check with the manufacturer to determine proper subcooling required for the model appliance you are evaluating.

1. Calculate the actual superheat the system is operating under. If the superheat is within = or –3°F of the manufacturer specifications, then the system passes the first test. Be aware that the superheat test in a TXV system only verifies the valve is operating as per manufacturer’s specification, and not an indication of proper charge.
  - o Suction Temp (dry bulb) – Evaporator Saturation Temp = Actual Superheat Temp
2. Calculate the actual subcooling. If the subcooling is within = or –3°F of manufacturer’s specifications the system passes the recommended refrigerant charge criteria for TXV systems. If manufacturer specifications are not available, use 10°F subcooling for 10 SEER systems and 15°F subcooling for SEER 12°F or greater.
  - o Condenser Saturation Temp – Liquid Line Temp (dry bulb) = Subcool Temp
3. If either superheat or subcool values are out of specified range (+ or –3°F), then the system fails the recommended refrigerant charge criteria. Check for loose or uninsulated TXV sensing bulb that is attached to the suction vapor line at the outlet of the evaporator.

### **37.3.5. Airflow Calculations: Evaporator Temperature Difference Method**

The evaporator temperature split method is designed to provide feedback that will ensure that indoor airflow is above minimum required for proper TXV and non-TXV system operation. Use the following steps to produce the calculations, and compare this with Table 2. If actual temperature difference is greater than = or –3°F, corrective steps must be taken to restore proper airflow. Once airflow is corrected, retest refrigerant charge and airflow again if refrigerant charge is adjusted.

1. Calculate the actual temperature split as the return air (dry bulb) temperature minus the supply air (dry bulb) temperature.

$$\begin{aligned} & \text{Temperature (dry bulb) of Air entering Evaporator coil} \\ & - \text{Temperature (dry bulb) of Air Leaving Evaporative coil} \\ & = \text{Actual Temperature Split} \end{aligned}$$

2. Determine the target temperature split from Table 2. Use return air (wet bulb) and return air (dry bulb) temperatures to determine the dry bulb temperature split.

Air Temperature (wet bulb) Entering Evaporator Coil

- Air Temperature (dry bulb) Entering Evaporator coil

= Target Temperature Split

- If the value is a dash (-), use an alternative method of determining adequate airflow across the evaporator coil. Proper airflow is between 360 and 400 cfm per ton of cooling capacity for both TXV and non-TXV systems.
  - If the actual temperature split is = or  $-3^{\circ}\text{F}$  for the target, the system passes the adequate airflow criteria.
  - If the temperature split is greater than  $3^{\circ}\text{F}$ , the system fails the adequate airflow criteria. Airflow must be increased and the system retested after the system has had time to stabilize again. Causes for low airflow can include: slow fan speed, high static pressure in the supply, return or both duct systems, dirty filter or evaporator coil, closed registers or balancing dampers.
    - Cooling Capacity (Btu/h)  $\times$  0.032 = required Airflow (cfm)
    - and then perform the following calculation:
    - Required Airflow (cfm) – Measured Airflow (cfm) = Airflow Variance (cfm)
  - If the temperature split is less than  $3^{\circ}\text{F}$ , then the system fails the adequate airflow criteria. Airflow must be decreased and the system retested after the system has had time to stabilize again. Causes for high airflow can include fast fan speed, leaky ducts, missing cabinet door.
3. Ensure that the thermostat, windows, and doors are returned to the original position before leaving the premises.

### **37.3.6. Compute Actual System Output**

1. On a Psychrometric chart, plot the dry bulb and wet bulb points for air entering the evaporator coil, and the dry bulb and wet bulb points for air leaving the evaporator coil. Grains of moisture in the air for each point can then be determined from the scale on the right side of the chart. Collect the following information:

Indoor Air Temperature (dry bulb) Entering Evaporator	◦
Indoor Air Temp (wet bulb) entering Evaporator	◦

Return Air grains of Moisture

Indoor Air Temperature (dry bulb) Leaving Evaporator

◦

Indoor Air Temp (wet bulb) Leaving Evaporator

◦

Supply Air grains of Moisture

- And perform these calculations:
- $\text{Return Air Grains Moisture} - \text{Supply Air Grains Moisture} = \text{Total Moisture Removed}$

Indoor Air Temp (dry bulb) Entering Evaporator

◦

Indoor Air Temp (Dry bulb) Leaving Evaporator

◦

Evaporator Temp difference

◦

### **37.3.7. Evaporative Cooling Viability and Options**

Evaporative coolers are very efficient at reducing the temperature of dry air by introducing moisture to the air that is brought into the home. Wet pads serve as air filters and humidifiers that cool, humidify and makes more comfortable the air that is introduced into the home. These appliances use no refrigerants and operate with less energy than air conditioners, and are a reasonable alternative to air conditioning in dry climates. Ninety degree air at 40% relative humidity can be effectively cooled to 77°F, while 100°F air at 15% relative humidity can be cooled to 76°F.

1. Sizing of coolers is based on a standard of 3 to 4 cfm per square foot of floor area and the performance is dependent on the replacement of dry air, with the cooler humid air. This requires that some windows in the home be opened to serve as exhaust for the dryer air. The circulation of conditioned air is controlled by the selection and location of the opened windows.
2. Evaporative coolers may be window or wall mounted and the ideal placement of the unit is out of the direct sun and away from any air pollutant sources or exhaust vents from the home.

## **38.0 Installation Practices—Test-Out and Documentation**

### **38.1. Scope**

Test-out is the comprehensive quality-assurance element of the home performance inspections. Regardless of the work that has been done and the resulting remediations, it's important to quantify and document the savings in an effort to calculate the customer's return on investment. This is important for you for any questions that may come up later regarding the work you've performed.

### **38.2. Tools and Materials**

Same as tools and materials for initial diagnostics.

### **38.3. Procedure**

#### **38.3.1. *Measure Effectiveness of Air Sealing***

1. It's important to ensure that we calculate the air leakage rates after all work has been performed. A blower door test needs to be performed during sealing work. The final test-out number should be the last number collected while sealing was in progress to see if there's additional work that needs to be done, and to make sure we have provided adequate ventilation. It's important to ensure that we calculate the air leakage rates after all work has been performed, so a blower door test needs to be used during sealing work. The final test-out number should be the last number collected while sealing was in progress to see if there's additional work that needs to be done, or to make sure we have adequate ventilation.
2. Conduct a blower door test under the same conditions as the original test was conducted – to determine the actual leakage rates of the building - before and after. Identify the amount of the reduction in terms of cfm, and comparing that to a reasonable goal. For example, a reasonable goal is the ASHRAE standard of "15 cfm for the building PLUS 15 cfm person (five person minimum) – OR the higher of those two numbers." In California, it's .35 air changes per hour under natural conditions (ACHnat) (or much less with added ventilation) – OR the higher of those two numbers.

#### **38.3.2. *Provide Performance Testing For All Installed Measures***

The following tests should be considered, depending on the specific work that has been performed.

1. "Worst case" combustion safety test should be redone if envelope sealing measures were taken.
2. Insulation installation: Use an infrared scanner to determine that the goal of the insulation has been reached.

3. Replaced appliance: Check to make sure that the savings expected is actually attained. A watt-hour meter can make this determination. Verify that water temperatures have been re-set to the suggested temperature.
4. Replaced heating system or “clean and tune:” Test for efficiency to make sure you’ve met the targets. And all vented appliances should be draft-tested and within standards, and also tested for carbon monoxide levels.
5. Ventilation leakage remediation: Exhaust fans and ventilation systems should be verified with regards to the quantity and quality (source) of the air flow. quantify the air flow.

### **38.3.3. *Provide Testing of All Systems that Maintain Interaction with Installed Measures***

Home systems are tightly integrated, and so it’s possible that by solving one problem, other problems have been created. Not only do you need to check the systems that you installed, but also consider existing systems that interact with the newly-installed systems. This may be a health and safety issue. For example, a newly-installed mechanical ventilation device placed in a laundry room could have a serious impact on the combustion appliance zone when certain doors are closed. Your most creative and vigorous testing needs to be done after your remediation efforts.

### **38.3.4. *Document All Systems Testing and Maintain Test Results***

You will want to make photocopies. Customers should get all appropriate documentation. You may also want to make photocopies of any information that might be relevant to you at some later date. For example, if the customer calls you with questions a year after services have been rendered, you would want to have the basic information available to you, so you don’t have to make a house call to answer a basic question.

## **39.0 Business Practices—Assuring Quality**

### **39.1. Scope**

This protocol covers recommended activities to assure consistent and adequate job and task quality as a means of enhancing the customer relationship, verifying staff performance, and providing information that may be needed by program sponsors in addition to the contractor's own reference files. This applies to all company activities, not just field retrofit jobs. These recommended steps are closely related to those of another protocol, Test-out and Documentation, and add to the data collected through that protocol's steps.

### **39.2. Procedures**

#### **39.2.1. *Create and Use a Standard Job Quality Assurance Process Routinely***

Develop and use a sampling process routinely to review jobs for quality. Some sponsor programs require specific sampling rates and procedures, although that step is typically the responsibility of independent reviewers. Contractors should still have their own process for quality assurance. If the contractor's test-out process is rigorous and well documented, only a small sample of jobs may be adequate. Some contractors may choose to integrate the test-out and quality assurance process, or rely primarily on the quality assurance step. In such cases the test-out results for all homes retrofitted should be reviewed.

Use and file a quality assurance form in the job file. This step provides valuable assurance to company supervisors (and program sponsors, if any) that quality is being maintained. Include all data recommended in this protocol, as appropriate for each job, as well as crew and homeowner comments and any remedial actions taken.

#### **39.2.2. *Review All Test-Out Data and Repair as Needed to Assure Adequacy and Accuracy***

Assure that the blower door test-out shows the expected and adequate degree of increased building envelope air tightness. The standard target is 0.35 air changes per hour. If this level is not reached, identify and note the reasons. Do additional air sealing work if conditions warrant. Note results.

Check to assure that the test-out of Combustion Appliance Safety was done completely and resulted in safe worst-case conditions. Include tests of combustion draft and adequate ventilation. Do additional home adjustments if necessary to assure safety, and note results.

Review the Duct Blaster test-out data to assure that adequate duct tightness was achieved per the requirements of California Title 24 and utility programs, where applicable, and local codes. Do additional duct sealing if necessary. Note results.

Confirm that the test-out data (notes, photos, infrared scanner results) for insulation improvements shows that insulation goals have been reached. Order further improvements if required. Note results.

Check test-out report to assure that proper airflow, refrigerant charge, and equipment efficiency have been achieved. Adjust as needed. Note final results.

### **39.2.3.      *Review all Job Notes and Comments For Indications of Any Problems***

Crew perspective: Here you should be alert for any crew reports of job problems such as inadvertent damage, installation difficulties, disagreements, scheduling delays, and customer problems of any kind. For each job reviewed, either find written crew comments on the job completion form or interview the crew foreman or field supervisor. Take any appropriate action to assure that all problems were successfully resolved. Note results.

Homeowner perspective: Customer satisfaction is crucial! Contact the homeowner directly and ask for assurance of job success and satisfaction. Note all comments for possible use in marketing. Remedy any reasonable sources of customer dissatisfaction. Take necessary actions to assure that lessons are learned by crew and management to avoid recurrence on other jobs. Record all comments, remedial actions, and resulting customer attitude.

### **39.2.4.      *Define and Use a Formal Dispute Resolution Process***

This is an important step in assuring that all staff understand how to deal with disputes effectively and exert all appropriate efforts to remedy them.

All disputes with customers are to be taken seriously and treated with respect. Staff are not to engage in arguments with customers, but instead report the matter to their supervisor for appropriate action.

Supervisors (who may be a field supervisor, job manager, or the business owner) should take all reasonable steps to resolve each dispute amicably. Even if the customer is wrong, it is generally worthwhile to satisfy them rather than risk their spreading warnings not to use this contractor, taking legal action, or causing other difficulties. Most unhappy customers are still reasonable and are often justified in their complaint.

Take detailed digital photos and notes on any pre-existing home and furnishings damage at the beginning of each retrofit and call the homeowner's attention to such damage, to avoid later disputes about contractor-caused damage. Keep these photos and notes with the job file until at least a year after job completion.

Include a dispute resolution clause in all job contracts, requiring all stalemated disputes to be subject to binding arbitration by a neutral accredited arbitrator. This minimizes the risk of costly legal action for both parties.

### **39.2.5.      *Instill the Importance of Quality Assurance in All Staff and Subcontractors***

Establish and emphasize a company policy of high quality standards and customer satisfaction in all aspects of the company's work, from marketing and lead handling to testing, sales, and

home repair. Connect that policy to bonuses for top quality performers and disciplinary action for habitually poor quality by both staff and subcontractors.

Train field supervisors to inspect regularly for quality and undertake immediate corrective action and on-the-job training to correct deficient practices by either staff or subcontractors.



## **40.0 Business Practices—Marketing Home Performance Retrofits**

### **40.1. Scope**

Having clear and effective marketing strategies is an essential element of any successful business. In Home Performance Contracting, marketing is most effectively used as a tool to differentiate a firm from conventional limited-scope and low-bid contractors. Understanding the market for potential customers, the media channels through which they are best reached, and general practices that increase visibility all play key roles in successful marketing efforts.

This protocol presents a set of guidelines and recommendations outlining activities that have been found to be successful for whole-house contractors.

### **40.2. Procedure**

#### **40.2.1. *Develop and Use a Consistent and Effective Marketing Message***

1. Stress the broad range of benefits, not just energy savings. Different homeowners may be interested in different benefits of home performance retrofits. Emphasis should be placed on the full variety of benefits offered by a whole-house solution. Based on California home performance buyer survey results, the most widely valued benefits of home retrofits appear to be indoor air quality improvement and family respiratory health, energy bill savings, comfort improvements, and environmental responsibility.
2. Home performance retrofitting is ideally marketed in association with the Green Building, Sustainability, and Solar Energy movements. Nothing is “greener” or more “sustainable” environmentally than saving energy, and home performance retrofits save the maximum possible in any given home. And home analysis and retrofitting complements solar energy installation by reducing the home’s energy requirement and size and cost of the solar array.
3. The CBPCA has effectively used “the healthy home solution” as a marketing concept, together with the national Home Performance with Energy Star branding.

#### **40.2.2. *Develop Marketing Materials for Public Distribution and Presentation***

1. Developing a set of table and handout materials for use at home shows and similar events will provide visual appeal for attendees, and communicate a thoughtful approach to the whole-house contracting business. It also allows efficient use of a contractor (or the firm’s representative) time and resources by having these materials on-hand in advance of the actual event. They should be periodically updated to include pertinent industry developments, new products/technologies, or compelling testimonials.
2. Potential customers will benefit from having a focused, succinct brochure that explains the services a firm offers. It should include the basic elements of the house-as-a-system concept, a list of its benefits and graphics illustrating these advantages (i.e., graphs representing energy cost savings), specific measures that are often overlooked by

traditional contractors, pictures of installations (before/after), quotes or testimonials from past customers, and the contractors logo and contact information.

3. Make use of all available marketing and sales aids from Home Performance with Energy Star, local program sponsors, and allies such as equipment manufacturers and suppliers supporting home performance contracting.
4. Contractors should have on hand a set of presentations that explain his or her business, tailored for a number of different audiences aside from potential customers. Presentations to local business groups can cultivate awareness in the whole-house concept as well as reinforce efforts to develop and maintain visibility in the community. Contractors should also be able to speak to trade organizations, homeowner groups, and educational entities. These efforts promote both the business and the house-as-a-system concept, with potential benefits on all associated levels.

#### **40.2.3. Use Existing Mass Media Channels Where Cost-effective**

Advertising in existing public media such as newspapers and TV reaches large audiences and can generate interest in the whole-house concept. This can position a whole-house contractor as the best of many alternatives for homeowners looking to hire a contractor.

1. Traditional media channels can be effective ways of reaching new customers, although costs can be prohibitive for many contractors. It is advisable to begin with ads in neighborhood or community “shoppers” for economy. Local cable TV is also relatively inexpensive but has not generally been cost-effective.
2. Considering the context of advertisement placement is extremely important. Home improvement sections of local newspapers as well as “home & garden” television and radio shows are good venues to reach potential customers who are already considering home improvement work.
3. All such mass media marketing should be well tested before making major financial commitments.
4. Insertion of information on home performance retrofitting in newspaper home improvement columns, where possible, is free and highly effective. A useful tactic is to offer a free diagnosis to a public figure or columnist as a way to create interest in an article. This requires effective “marketing” to the columnist.

#### **40.2.4. Create Your Own Marketing Initiatives Beyond Mass Media**

1. Maintaining a website with a full list of services offered, contact information, customer inquiry and feedback capabilities, links to outside information for educational purposes, and customer testimonials will support efforts made to market through other media outlets. A basic, professionally designed website with these elements can be constructed for around \$1,000, with a small ongoing charge for the website hosting service.

2. Periodic newsletters, both conventional and electronic, can be created to include new developments in the whole-house contracting industry (including new products and news items relating to health/safety and energy efficiency) highlight success stories, and educate customers to generate ideas for potential future work.
3. Home shows and similar events allow access to a captive audience already interested in home improvement and investment. They provide an excellent opportunity for educating potential new customers, and positioning a contractor as being on the leading edge of his or her industry. They also provide opportunities for networking with dealers and manufacturers, educational organizations, professional associations, and other contractors.
4. A press release for distribution to media channels in advance of a home show, trade show, conference, or similar event can provide low or no-cost advertising for a business, as well as lend credibility to the firm as a player in the repair/retrofit/remodeling industry.
5. There are instances where non-traditional venues such as home improvement stores, environmental expositions, and health fairs can provide well-focused audiences for marketing efforts. These provide an opportunity to promote either groups or an individual firm where competitors are likely not present, which helps differentiate a firm and create an impression of unique value. Successfully identifying these “guerilla marketing” opportunities can provide a competitive advantage over businesses that rely solely on traditional channels.
6. While contractors generally compete with one another for work, there are often contractors or firms that specialize in services that complement one another. Aligning with contractors that subscribe to the whole-house concept but have expertise in a different area can boost the competitiveness of each party involved.
7. While on the job, contractors can advertise their services in the local neighborhood with little additional effort or expense. Well-designed truck signs, door hangers, and job signs left in the yards of customers are all effective and low cost advertising strategies that can be performed by the on-site staff.

#### **40.2.5.      *Make Use of Existing Customer Base for Repeat Business and Referrals***

1. Marketing to your own past customers: existing customers are extremely valuable sources of potential future jobs. Having made the decision to hire a firm in the past, they are already the product of a successful marketing effort. The first step in marketing to past customers is to ensure their satisfaction with the work initially done. Customer surveys can provide invaluable insight into what specific elements of past work they found most valuable, as well as what aspects of the job could use improvement.
2. Getting referrals from satisfied customers is a major source of new business. They provide a qualified recommendation that a contractor does quality work, and customers often provide referrals to other homeowners who they know are considering work done

on their home. Each successful completed job should result in several potential future jobs.

#### **40.2.6. *Make Use of Existing Organizations and Groups as Allies and Branding Sources***

1. The vast majority of successful companies in all consumer-based industries have developed a unique “brand” that creates independent associations in the consumers mind. A company name and logo go beyond just identifying the company in words and symbols, and convey essential elements of the business and what it hopes to bring to consumers who use it. Contractors should employ their use of the “house-as-a-system” concept to define their business. The whole-house strategy of home repairs, retrofits, and improvements differentiates a contractor from most or all of his competitors, and this distinction should be exploited in the public display of a contractor’s business.
2. Contractors can use existing “brands” to bolster the effectiveness of their own firm’s branded image. Home Performance with Energy Star is an implicit third party endorsement, and for broader linkage to environmental concern selected residential “green” contracting associations such as Build It Green could be used. As an emerging home performance contractor trade association, the CBPCA logo and brand can also be leveraged to provide credibility to an individual contractor’s business.
3. Contractors can benefit greatly from taking available opportunities to join groups that encourage networking and information sharing among colleagues. They can provide valuable insight and qualified references for subcontractors, business services, media outlets, and informational resources that might not otherwise be known to the individual contractor. Active participation also increases visibility in the firm’s community and among potential customers.
4. The whole-house concept requires contractors to stay abreast of the latest developments in building science. Outreach to local educational organizations, professional associations, and similar entities can lend credibility to a firm as one that is dedicated to providing the best possible services to homeowners. Inclusion in different efforts by organizations in the building sciences industry also provides visibility for a firm via inclusion in any promotional materials associated with the activities.
5. Customer educational workshops through local schools, public service organizations, city agencies, churches and other groups can be excellent opportunities to generate repeat business, referrals, and new customers. A well executed workshop will allow a contractor to discuss in-depth the whole-house concept, practical applications, diagnostic techniques, and a chance to discuss any concerns homeowners have in advance of any work being done. They can also generate interest among potential customers, and position the firm as the logical choice for customers looking to have work done. They can also provide impetus for referrals by attendees.

## **41.0 Business Practices—From Leads to Home Inspections**

### **41.1. Scope**

Once marketing has generated inquiries or leads, it is important for contractors to take all steps available to turn the lead into an opportunity to test the home. A strategy for lead handling and conversion into a home diagnostic inspection should be developed that includes elements such as screening, scheduling, diagnostic visit protocol, and customer education. This strategy should seamlessly transition into a diagnostic visit plan that concludes in a proposal for home improvement.

### **41.2. Procedure**

#### **41.2.1.        *Respond Effectively to Leads***

1. Leads must be prescreened and qualified before investing effort in the home diagnosis and sales process. While all leads should be treated as a potential sale, it is important to develop a process by which a contractor determine whether or not there is a reasonable likelihood that the customer will end up deciding to hire the firm. The initial step is to gauge interest. The customer should demonstrate an active willingness to learn more about the diagnosis and remediation process, and be open to discussing the next steps. Customers should also be qualified to make the decision to hire a contractor, and have access to capital or financing options. This can often be done in a single telephone conversation
2. The response to telephone and web inquiries, as well as leads gained from outside sources such as satisfied customers or home shows, must be highly organized. Gathering homeowner information in an organized, systematic way will not only streamline the initial diagnostic appointment set-up process, but allow the best remediation strategy to be developed in a minimum amount of time. All personnel who deal with such leads must be trained and scripted in an appropriate response and screening process. A designated telephone number for home performance jobs can be advertised to better distinguish for internal staff the unique preliminary information gathering requirements of whole-house jobs.
3. After collecting all pertinent customer information, all efforts should be made to schedule an inspection during the initial phone contact. This encourages the homeowner to move towards making the decision to hire a contractor.

#### **41.2.2.        *Make Clear Arrangements For the Diagnostic Visit***

1. If possible, the initial home inspection should take place with all decision makers present. It ensures that the concerns of all parties are best able to be addressed, and minimizes the risk that a contractor will visit a home where one or more of the homeowners are not committed to a remediation project.

2. It is typically possible for homeowners to obtain historical utility billing data from their utility, usually with a simple telephone call. This data is very important and should if possible be obtained by the homeowner before the diagnostic visit. Understanding what energy usage patterns the home operates under, and what energy costs the homeowner typically incurs is an essential step in whole-house projects. Obtaining this information in advance of a visit allows that contractor to target specific concerns and potential solutions during each step of the diagnostic process. It also encourages the homeowner to actively consider what aspects of their home's performance are of primary concern.
3. Customers will be most receptive to the whole-house concept if they are given the opportunity to learn more about it in advance of an initial diagnostic visit. Once an appointment is confirmed, a prepared set of materials should be sent to the homeowner explaining the house-as-a-system concept, the process, and any additional information pertinent to the contractor's work.

#### **41.2.3.      *Establish a Pricing Strategy For the Home Diagnosis and Evaluation***

1. Contractors can use a number of different strategies to determine the price of a diagnostic inspection and report. Some common options include:
  - Pricing the home inspection based on demand
  - Using inspections as a loss leader, and considering the loss as a marketing cost
  - Pricing for maximum appeal (trial and error) and considering the remainder of the cost as an overhead expense
  - Contractors should consider carefully what role they want the inspection to play in their business (marketing, revenue source, etc.) and tailor a pricing strategy accordingly.
2. Contractors may want to consider offering a free inspection and estimate in certain circumstances. This activity should be limited to prevent homeowners who are not committed to hiring a whole-house contractor from draining limited time and resources from the diagnostic team, however there may be instances where it can be an effective tool in securing a job. Contractors should have a set of pre-defined conditions under which these free estimates are provided.

## 42.0 Business Practices—The Diagnosis and Sale

### 42.1. Scope

Once leads have successfully been generated, it is important for contractors to take all steps available to turn the lead into an inspection and then an actual job. A standard practice should be developed for scheduling and conducting the home diagnostic inspection. This strategy should seamlessly transition into a post-diagnostic visit plan that concludes in a successful closed and documented sale.

### 42.2. Procedure

#### 42.2.1. *Perform the Home Inspection and Develop a Proposal*

This section covers general procedures. Technical details of the home diagnostic inspection are covered in a separate set of protocols for that purpose.

1. Performing the site inspection and diagnosis is often the homeowner's first in-person experience with contractor. Care should be taken to leave the impression of a knowledgeable, experienced professional.
2. The site inspection provides a valuable opportunity for a contractor to educate the customer about his or her business, the diagnosis and remediation process, and the house-as-a-system concept as well as the specific findings of the inspection.
3. Include the customer in the diagnostic process. The contractor should take every opportunity to engage the customer throughout the initial diagnosis. Communicating what specific techniques are performed and what data is collected during the process will allow a smooth transition to the estimate and signing of the contract to perform the remediation measures.
4. Contractors should inform customers fully of the steps that will be taken to test their homes and determine what remediation strategies will eventually be recommended. Customers should be aware of what areas of their home contractors will need access to, and whether they need to inform the contractor of any potentially hazardous conditions that may occur during the diagnostic process.
5. For most home performance contractors, the diagnostic visit is not a sales call; a later visit is made after completing a diagnostic report and a proposal for improvements and costs. A few contractors have found it feasible to collapse those steps into a single visit, typically staffed by two people, in order to reduce total time and cost. This requires a highly automated analysis, report generation, and proposal development process, and is a later option after experience is gained with the two-visit process.
6. Contractors should make clear to customers that their role is as essential (if not more so) as any equipment or installed measure in ensuring the proper functioning of their home. Helping homeowners become aware of the activities that affect comfort, safety, energy usage, and durability is one of the most valuable services a contractor can provide. As part of engaging and including the customer in the diagnosis process, a contractor

should use the inspection to explain the interactions between occupants and home performance.

7. A contractor should not leave the home after performing an inspection without scheduling a follow-up visit or appointment to discuss the proposed remediation strategies.

#### **42.2.2.      *Develop and Employ an Effective Home Retrofit Sales Process***

1. Prepare and use a presentation book in the sales visit. A presentation book can help contractors illustrate in simple terms the different elements of the whole-house diagnosis and allow the customer to feel active and involved in the inspection process. Books should contain plain-language explanations and illustrations of the tests performed, information collected, and elements of the evaluated home (HVAC, ducts, insulation, etc.).
2. The comprehensive “house as a system” approach to home remediation provides a range of benefits to homeowners. This should be communicated clearly and consistently throughout the sales process. Communicating the value of the job not just from an energy cost savings standpoint, but also in terms of the health, safety, and comfort of their families can be a big factor in leading them to choose a more comprehensive and effective remediation strategy.
3. Potential customers will appreciate a contractor who has a prepared set of credible information on experience and qualifications. This information should include range of expertise, history, references, and success stories. Contractors should also take care to keep this information current to reflect recent projects and any additional training or qualifications that may be acquired.
4. Ability to offer attractive financing is a major advantage. Whole house contractors will often recommend projects that exceed the proposals of their competitors in scope and cost. Offering financing can help homeowners who may initially be reluctant to consider a contractor that is not operating in a competitive low-bid environment. It also gives the contractor an opportunity to confidently describe the lifetime costs and the full range of benefits associated with the job.
5. Inform the customer of utility incentives applicable to the retrofit, if any. Local utilities often have programs offering rebates or other incentives to homeowners that install energy efficient HVAC equipment, lighting, windows, or weatherization-related measures. Contractors should find out what specific incentives are available in their service area, and be prepared to inform customers of these incentives upon recommending any related strategies.

#### **42.2.3.      *Close and Document the Sale***

1. Upon completion of the test process and determination of recommended strategies, the sale should be documented and a contract signed as quickly as possible. Contractors

should make sure they or someone from their staff is available to answer any questions about the job. Every effort should be made to encourage the potential customer to resolve any issues they may have that would lead them to be reluctant to sign a contract.

2. Follow up very shortly after the contract is executed to establish a job schedule and details of site storage, truck parking, protection of furnishings, etc.



## **43.0 Business Practices—Field Activities Infrastructure**

### **43.1. Scope**

Aside from ensuring a well-run, profitable business, the development and maintenance of an effective supporting foundation for the field work will enhance quality and generate new business. These infrastructure activities will improve efficiency and maximize the success of a home performance contracting business. This protocol provides a set of guidelines and recommendations outlining supporting activities that have been found to be successful for whole-house contractors.

### **43.2. Procedure**

#### **43.2.1. *Select, Set, and Enforce Performance Standards For Subcontractors***

Subcontractors are often an essential part of whole-house jobs, as the scope of work is often comprehensive enough to go beyond the scope of any individual's expertise or availability. Choosing a qualified subcontractor is as important as choosing full time staff, as ultimately it is the general contractor's name on the work done.

1. Be sure to check references for all subcontractors, and outline in detail all work to be done, quality and completeness standards, and compensation to be provided.
2. It is highly recommended to require subcontractors to have instruction in basic building science principles and best practices, since often the conventional practices are faulty. This protocol set's technical protocols provide an entry into those principles and practices.
3. Check all work done to ensure quality before payment is made. Insist on consistent quality standards for all work.

#### **43.2.2. *Maintain and Use a Variety of Testing Equipment***

1. A full and properly maintained set of diagnostic testing equipment is essential for the inspection and sales process. Each crew should be fully trained in its operation, and a process should be in place to assure its proper maintenance. In addition, it is important to make sure that all crews have access to testing equipment when they need it. This assures the most efficient allocation of time and resources for verification of performance improvements made. It also assures that potential customers are given a positive impression of a business and its on-site workers.
2. Maintain and use equipment necessary for "clean and tune" services. Having a full set of clean and tune equipment maintained and regularly used not only allows for additional revenue from these jobs, but allows easy access to prospective customers. Having a technician available to do regular clean and tune visits provides an automatic opportunity to recommend a whole-house inspection and/or potential work with the customer already present and aware of their HVAC systems.

### **43.2.3.        *Develop or Use Existing Standardized Installation Specifications***

A set of standards should be in place that outlines diagnostic procedures and by which remediation strategies for each home are determined. A number of regulatory codes outline standards for new construction and retrofit jobs, and trade associations such as the CBPCA and the Building Performance Institute generally have standards available to all contractors who are members.

### **43.2.4.        *Deliver Product Specifications, Warranties, and Maintenance Requirements***

Contractors should provide detailed specifications on all work done at each site, including fact sheets on all installed equipment. This not only allows for easier maintenance of installed equipment and measures by the homeowner, but also provides a permanent point of reference for anyone in the future who needs more information about specific work done to the home.

Beyond the California one-year construction job quality warranty required of contractors, warranties of suppliers backing the performance of installed equipment or other measures can be an effective sales tool. Upon completion of the job, documentation of any such warranties should be provided to the customer. In addition, a sticker can be affixed to all installed equipment that states that the unit is under warranty, and provides contact information if service is needed.

## **44.0 Business Practices—On-Site Job Management**

### **44.1. Scope**

Contractors should have in place a set of procedures that dictate steps and requirements of each job. These procedures should be communicated to the crew and all subcontractors. Doing so will ensure the safety of the occupants and crew, quality installations, minimal callbacks, and maximize customer satisfaction.

### **44.2. Procedure**

#### **44.2.1. *Keep Home Clean and Undamaged***

The contractor and crew should take every precaution to leave the home clean, undamaged, and as undisturbed as possible during the job. Homeowners will most likely remain living in their homes during the installation process, and as such they want a minimum of disruption to their living quarters. Drop cloths, dust covers, and other protective measures should be used as standard practice. The site should be left clean, orderly, and safe each night. In the event that some damage does occur, it should be fully and immediately documented and reported to the homeowner.

#### **44.2.2. *Use Digital Photos to Document Work and Avoid Damage Claims***

Using a digital camera during the installation process can be a very effective tool in documenting progress, as well as avoiding any claims the owner might make for damage that the crew is not responsible for. A simple photographic record of progress made (either each day or when applicable) is quick and can be done easily by any member or the installation team.

#### **44.2.3. *Communicate Job Requirements to the Installation Crew***

The contractor should take care to communicate clearly the specific job requirements of every crew member. Whether subcontractors or in-house staff is used, each component of the job should be identified in as fine a detail as possible, and assigned to a specific crew member for completion or overseeing.

#### **44.2.4. *Follow Health and Safety Precautions***

Assuring the safety of the workers and occupants in the house during the job should be the first priority of a contractor. The contractor should develop and incorporate a set of safety procedures to be used on the job, and each crew member should be fully aware of these procedures. Steps should be taken to assure all procedures are followed, and periodic meetings to refresh and reassert the importance of these procedures are also recommended.

#### **44.2.5. *Use an Effective Standardized Job Closeout Process***

1. A standard checklist for job closeout procedures can help assure a satisfied customer and minimize callbacks. The checklist should assure that all measures are installed correctly, functioning, and do not pose any hazards to the occupants. It should also include a thorough walk through to assess any damage and ensure the home is left undisturbed and all tools or equipment are removed.

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2. Once all work is complete and the crew has completed the job closeout checklist, the contractor should make sure to get the homeowners signature acknowledging the job completion. This will ensure that all unresolved issues are answered to the full satisfaction of both the customer and contractor, and also minimize callbacks.

## **45.0 Business Practices—Job Followup Activities**

### **45.1. Scope**

There are a number of actions a contractor and his or her firm can take after the completion of a job to ensure ongoing customer satisfaction, loyalty, and maximize the benefit of referrals. These activities also allow the contractor to refine the diagnosis and remediation process to make it more effective and ultimately more profitable.

### **45.2. Procedure**

#### **45.2.1.      *Develop and Use an After-job Evaluation Form to Learn From Each Job***

Contractors should develop and distribute an job evaluation form for customers who have had jobs completed. The evaluation should be relatively concise, but also gauge the satisfaction with all relevant aspects of the job, including installation crew performance, performance of installed equipment and measures, associated comfort and safety impacts, and energy savings. These surveys should be compiled and periodically evaluated by the firm to determine if any areas for improvement are consistently cited, and if progress has been made addressing any issues common to customers.

#### **45.2.2.      *Close Out the Job With Good Customer Relations***

1. After each completed job, it is important that the homeowner be informed of the home's improved performance. This is based on post-retrofit testing and inspection. This test-out allows the contractor to not only evaluate the effectiveness of his crew, but to provide the homeowner with specific documentation on the quality of the work done.
2. A Home Performance with Energy Star certificate should be left with all customers after the completion of the job. This allows the customer to be assured of the quality of work done, and provides documentation for the homeowner should he or she decide to sell or appraise the home after remediation has occurred.
3. Ask for referrals. Referrals from satisfied customers are the most effective way for a firm to target potential future customers, and home performance retrofit customers tend to be very satisfied due to the variety of benefits gained. A satisfied customer who is personally familiar with another homeowner will be much more convincing than any printed testimonial. It also generates word-of-mouth advertising for a specific firm and the house-as-a-system concept in general.

#### **45.2.3.      *Follow Up Periodically With Customer After the Job is Done***

1. Contractors should schedule follow up calls to customers after the job has been completed to ensure the ongoing satisfaction of the homeowner. These calls should allow a fairly significant amount of time to have elapsed, at least 6 months to one year. This will allow seasonal variations in the requirements of heating, cooling, insulation, and envelope to be fully demonstrated.

2. Contractors should try to collect energy bills for a full year after the completion of a job, and estimate the home's actual realized energy performance. This will allow contractors to refine their evaluating and estimating techniques, as well as to give the customer a comprehensive picture of the energy effects that the job has had.
3. In cases in which not all recommended measures were funded initially, it may be appropriate to arrange a possible Phase Two work program to complete the retrofit.

## **46.0 Business Practices—Planning and Management**

### **46.1. Scope**

Aside from ensuring a well-run, profitable business, the development and maintenance of an effective set of business practices will invariably work to generate new business. Creating systems for internal activities including hiring, developing job descriptions, training procedures, and performance evaluations, all help maintain a smooth and efficient flow of business activities. External activities such as customer service, quality assurance, and participation in trade associations and conferences work to increase a business's visibility and develop the capabilities of the contractor and his or her employees. Together, these strategies and activities can be employed to maximize the success of a business and ensure that its goals for the future are met.

### **46.2. Procedure**

#### **46.2.1. *Define Business Model to be Used and Develop Business Plan to Move to New Business Model***

1. Contractors have choices in how to implement home performance retrofit contracting. They can either add this new business to their other already existing business lines, or transition their entire business into home performance contracting. There are also different ways to organize the home performance process.
  - A contractor may decide to do everything in-house, although smaller contractors in particular can often find that approach too disruptive and risky to their livelihood.
  - Others may prefer to continue their present contracting business and ally with other individuals or firms that specialize in the new elements of marketing, home diagnostics, and quality assurance.
  - There are many variations within those general models. Each contractor can move into home performance in the way that works best for that organization.
2. In order to successfully make the transition to incorporating the home performance concept into future sales opportunities and jobs, it is important that a comprehensive business plan be developed that outlines all the aspects of a contractor's current activities, how they will be altered or complemented with new home performance functions to suit the contractor's particular preferences and capabilities. Include all elements of both day-to-day operation and long term strategies, including staffing, training, equipment, operating costs, desired business growth, and how all this fits into the contractor's existing business. This includes a stepwise transition plan that implements the contractor's new whole-house business model. This merely assures that the new building performance retrofit capabilities and business are implemented smoothly.

#### **46.2.2.      *Secure Adequate Funding For Cash Flow Management***

1. Different contractors will have different capital needs. Home performance retrofit jobs tend to be longer than most HVAC jobs, but shorter than most remodeling jobs, and cash flow needs will differ. Having access to a line of credit will help assure that sufficient capital is present to help cover cash flow for client payment delays and the financial strains of business growth.
2. Before beginning any job, partial payment in advance should be available to cover costs associated with the startup and materials ordering for the project. For larger and longer jobs, progress payments should cover labor, materials and installed equipment, and associated overhead.

#### **46.2.3.      *Provide Training and Continuing Learning Opportunities For Staff***

1. Use training, apprenticeship, and certification to build quality staff. For skilled positions, employers should have a training process developed that covers all aspects of the job and allows new employees to gauge how well they are performing and developing their skills. An apprenticeship system can allow one-on-one training by a more experienced employee while on the job, and assigns a level of accountability for the development of newer trainees. Certification provides longer term goals and benchmarks for training that employees can use to evaluate the capability of their staff.
2. Employers should remain aware of outside training and continuing education opportunities. These allow staff to bolster their qualifications, network with others in the home performance industry, and perform better work. Trade press, internet forums, email lists, and trade events are all good sources for information on training courses offered in your area.
3. Offer mentoring opportunities to senior staff and their assistance to others. A mentor relationship can provide benefits to both the mentor and the individual being mentored. Relationships are developed that extend beyond any temporary or shorter term affiliations with businesses or employment positions. These can lead to alliances and partnerships that yield benefits for the duration of one's career. They also provide a unique channel for cultivating valued attributes and ideas within an individual's own firm or industry.

#### **46.2.4.      *Provide Support and Incentives to Motivate and Keep Quality Staff***

1. Offer benefits and pay increases to retain proven quality staff. Whole-house contractors can position their business outside of the traditional low-bid market, and develop a steady stream of business even if charging more than other contractors in the same region. Accordingly, more qualified staff should be hired to ensure that premium-level services are delivered to customers. Attracting the best applicants can require higher salaries and/or benefits that may not be offered by competing contractors.

2. All employees should have a clear picture of their duties and responsibilities both in general and on a day-to-day basis. These should be outlined up front in the hiring process and communicated clearly via a job title/description. Effective managers will also evaluate an employee's specific capabilities on an ongoing basis, and tailor their duties to emphasize the individual's strengths as well as the ongoing needs of the business as a whole.
3. Developing a set of performance incentives for crews will both assure quality work on present jobs and increase the likelihood of repeat customers. Incentive structures can be based on customer satisfaction, energy savings, test-in/test-out conditions, or other appropriate metric. Having an objective set of performance standards and a method by which the work done can be evaluated will also cultivate consistency in the work done by a crew.
4. Regular performance reviews of employees ensure that they have an accurate sense of how well they are performing, what areas need improvement, and what potential for advancement they may possess. They also provide opportunities for employers to get feedback on their management strategies, and the business in general. These reviews should take place at least once a year, and performance review questionnaires should be developed to structure the discussion between employers and employees. Topics for discussion should include employee strengths/weaknesses, goals for the upcoming performance review period, evaluation of success in meeting previously outlined goals, and salary review considerations.

#### **46.2.5.      *Develop Professional and Business Relationships and Access to Knowledge***

1. Contractors can effectively generate business by entering into referral agreements and incentive-based relationships with other contractors. These relationships allow each party involved to benefit from marketing and outreach activities performed by others, as well as the direct incentive offerings such an agreement provides.
2. Conferences can be one of the greatest investments in time and resources for a whole-house contractor. They provide attendees with multiple opportunities for the advancement of an individual employee's knowledge, as well as the betterment of the business he or she is affiliated with. They often offer customized workshops and educational offerings, as well as a tremendously effective venue for networking and industry insight. They allow personal access to industry leaders, often from different areas of the country, manufacturer representatives and new technology offerings, and regulatory or other governmental agencies.
3. Participation in trade organizations is an effective way of providing visibility for a company, as well as keeping abreast of issues affecting local businesses. Trade organization membership is generally offered on an annual basis for relatively little cost. Besides the direct benefits, it also offers intangible benefits associated with community participation.

4. Email list serves can be a valuable source of information on upcoming industry events, news items and developments, and general networking. They are typically provided at no cost to recipients, and are easily available to any individual with a working email address.
5. Contractor support groups, such as bulletin board Q&A systems and roundtables, should be considered as tools for taking advantage of the knowledge of others and the potential for developing valuable relationships.

#### **46.2.6.      *Create Supporting Processes and Activities***

1. Effective tracking of the sales closing rates and time from inspection to report allows a contractor to best identify the individuals or steps in the process that need attention. They also provide a clearer sense of actual costs associated with the sales process.
2. An established pricing system not only saves valuable time for contractors in the inspection and estimation process, but it allows better tracking of costs and profits. It also allows a contractor to better meet the individual needs of a customer by providing the means to detailing all the cost components of a job. Contractors should also have financial tracking systems in place to compare estimate to the cost of the actual installation. This will allow refinement of the pricing system for future estimates.
3. A detailed process for assuring quality work in all jobs and customer relations should be in place. This should include which specific employees are responsible for inspecting completed work, fielding customer service inquiries, mitigating any issues that arise, and communicating the results to the contractor and customer.

## 47.0 Glossary

ACCA	Air Conditioning Contractors of America
ACEEE	American Council on an Energy Efficient Economy
ACH	air changes per hour
ACHnat	air changes per hour under natural conditions
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BP	building performance
BPI	Building Performance Institute
Btu	British thermal unit
CAZ	combustion appliance zone
CBPCA	California Building Performance Contractors' Association
CDD	cooling degree days
cf	cubic feet
CFM	cubic feet per minutes
CO	carbon monoxide
CPUC	California Public Utility Commission
DHW	domestic hot water
Energy Commission	California Energy Commission
EPA	Environmental Protection Agency
ft <sup>2</sup>	foot square
HDD	heating degree days
HERS	Home Energy Rating System
HUD	U.S. Department of Housing and Urban Development
HVAC	heating, ventilation, and air conditioning
IAQ	indoor air quality
in <sup>2</sup>	inch square
IR	infrared

kW	kilowatt
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
low-e	low-emissivity
MW	megawatt
NFP	not-for-profit
NFRC	National Fenestration Rating Council
NP	non-participant
OSB	oriented strand board
PATH	Program on Advanced Technology in Housing
PG&E	Pacific Gas and Electric Company
PIER	Public Interest Energy Research
PP	partial participant
ppm	parts per million
RD&D	research, development, and demonstration
SEER	seasonal energy efficiency ratio
TRC	Total Resource Cost
VOCs	volatile organic compounds
WAP	Weatherization Assistance Program
WH	whole house