

Ceiling Insulation Survey Information

Site Visit Protocol (product 5.2.2b)

Report on Phone Surveys (product 5.2.3)

Insulation Cost and Application Study (product 5.2.6)

TECHNICAL REPORT

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Gray Davis, *Governor*

CALIFORNIA ENERGY COMMISSION

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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.

This document is one of 33 technical attachments to the final report of a larger research effort called *Integrated Energy Systems: Productivity and Building Science Program* (Program) as part of the PIER Program funded by the California Energy Commission (Commission) and managed by the New Buildings Institute.

As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The *Integrated Energy Systems: Productivity and Building Science Program* research addressed six areas:

- Productivity and Interior Environments
- Integrated Design of Large Commercial HVAC Systems
- Integrated Design of Small Commercial HVAC Systems
- Integrated Design of Commercial Building Ceiling Systems
- Integrated Design of Residential Ducting & Air Flow Systems
- Outdoor Lighting Baseline Assessment

The Program's final report (Commission publication #P500-03-082) and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the *Integrated Energy Systems: Productivity and Building Science Program*. The final report and attachments are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This attachment, "Ceiling Insulation Survey Information" (Attachment A-26) provides supplemental information to the program's final report within the **Integrated Design of Commercial Building Ceiling Systems** research area. It includes the following reports:

1. **Site Visit Protocol.** Instructions and survey forms used in the site visit inspections of buildings with lay-in insulation.
2. **Report on Phone Surveys (200 Buildings).** Memo about the objectives and methods of the telephone surveys that investigated ceiling insulation characteristics in commercial buildings.
3. **Insulation Cost and Application Study.** Report that presents the cost calculations for different types of insulation for a prototypical commercial building. Also presents a summary of the information collected in telephone surveys conducted with architects.

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced these documents as part of a multi-project programmatic contract (#400-99-413). The Buildings Program includes new and existing buildings in both the residential and the non-residential sectors. The program seeks to decrease building energy use through research that will develop or improve energy efficient technologies, strategies, tools, and building performance evaluation methods.

For other reports produced within this contract or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. All reports, guidelines and attachments are also publicly available at www.newbuildings.org/pier.

ABSTRACT

The “Ceiling Insulation Survey Information” attachment is a set of three documents produced by the Integrated Design of Commercial Building Ceiling Systems project. This was one of six research projects within the *Integrated Energy Systems: Productivity and Building Science* Program, funded by the California Energy Commission’s Public Interest Energy Research (PIER) Program.

When this project began, California energy codes allowed the use of lay-in insulation on top of dropped (T-bar) ceilings. This insulation method is fairly common due to its low installation cost but anecdotal reports indicate that insulation integrity is not maintained over time. As part of this research project, researchers surveyed commercial buildings to identify how many have lay-in insulation and what fraction of the lay-in insulation remains in place; researched application and cost issues of lay-in insulation versus alternative insulation methods; and calculated the energy and energy-cost impacts of these approaches. The results are in the program’s final report (Commission publication #P500-03-082) and the “Ceiling Insulation Report” (Attachment A-14).

This attachment (A-26) includes three background documents: 1) Site Visit Protocol; 2) Report on Phone Surveys; and 3) Insulation Cost and Applications Study. It includes the forms and methods used in the field visits; the objectives and methods of phone surveys of 200 buildings; cost calculations for different types of insulation; and a summary of telephone surveys conducted with architects.

These reports contributed to the research conclusion that lay-in insulation does not form a reliable thermal barrier and a 2005 Title 24 recommendation to disallow lay-in insulation in new commercial buildings in California.

Authors: Jon McHugh and Mudit Saxena, Heschong Mahone Group

Keywords: Title 24, insulation, lay-in insulation, suspended ceiling, dropped ceiling, T-bar, commercial building ceiling, roof deck insulation

Instructions

Building Overview (Overview Sheet):

- Interview site contact about building construction, building age and recent remodels.
- Find out if recent remodels involved accessing the top floor ceiling plenum or replacing the ceiling tiles.
- Find out if roof has been recently replaced and if they know or have plans to indicate how much insulation is under the roofing.
- Ask building contact their estimate of total floor area.
- Roof code on overview sheet should match roof codes on entire building sketch
- If more than one occupancy directly under a given roof type, list the second occupancy and the the percentage of the roof type above that occupancy.
- If there are more than two occupancies under a roof type, add another roof type.

Draw a quick sketch of the entire building and include:

- Draw two directional arrows:
 - 1) one for true north and
 - 2) a nominal north aligned with a major building axis
- Approximate dimensions of roofs. Draw a line between roofs of different heights
- Place ID numbers on building sketch of locations that measurements were made
- Draw a circle around the measurement points indicating observable plenum areas
- Observable plenum areas are where you can see if ceiling tiles are insulated or not.
- Label each roof type with its roof code (R1, R2, etc.)
- Label each wall type with its wall code (W1, W2, etc.),
- Each major wall orientation should be labelled with a wall code.
- If there is more than one wall type along a building orientation, draw labeled arrows with the wall index on the sketch with the estimated length
- Indicate where there are roof vents or grills. An observation of what lies under the roof at this point may be needed to determine if it is a vent or HVAC exhaust

Detailed Plenum Observation (Observation Sheet):

- Observation # on sheet should be referenced on whole building sketch
- Observation # on sheet should be referenced on whole building sketch
- Distance of view: write down distances in each direction of observable plenum areas
- Observable plenum areas are where you can see if ceiling tiles are insulated or not.
- Under each view distance indicate what obstruction limits the view.

AHU= air handling unit, none = no solid obstruction

- Write down the times or slide numbers of photos taken.
- Plenum height: the average height in the observable plenum area
- Plenum ventilated: look for grills or other openings to the outside
- Plenum wall: You may need to ask the building contact about wall insulation for finished plenum walls. If no info assume same as conditioned space wall.
- Vapor barriers: Indicate if it is plastic or foil faced - if none write "No"
- Temperature measurements: take measurements in plenum just under the roof deck, at 2/3ds the plenum height and at 1/3 the plenum height. Take measurements away from ductwork and away from open tile (use stick to hold sensor away from opening).
- Note grid dimensions, the area of each grid opening will be used for accuracy check
- Make note of insulation coverage over tiles by counting the number of tiles that are

Instructions

completely covered, partially covered, and totally uncovered. Then total the counts

- Similar notes are taken for recessed lighting fixtures - troffers and recessed cans.
- Tile surr 2'x 2' and Tile surr Cans refers to the partial tile around these fixtures - is it covered with insulation.
- Also indicate if fixtures are unventilated (no air movement holes), ventilated, or are connected to ducts (heat extract).
- Multiply total lighting fixture and tile counts by their areas to estimate their total area
- Enter square footage (not counts) of diffusers, speakers etc. and of the tile surrounding these devices in the appropriate boxes.
- Add up the total square footage of all elements observed. This should be close to the same value of the total SF at the top of the sheet (error checking).
- Use the back of the observation sheet to take any further notes and the plenum observation sketch.

Plenum Observation Sketch:

For each detailed observation of the ceiling plenum, draw a quick plan sketch.

- Label the sketch with the building ID number and the observation number.
- Observation number should be referenced on whole building sketch

Each sketch will contain the following:

- the direction of nominal north aligned with the major building axis
- approximate dimensions of ceiling area
- approximate locations of ducts
- approximate locations of recessed fixtures
- locations of walls extending through the ceiling
- locations of skylights
- locations of temperature measurements (and record height above ceiling)
- direction(s) of roof slope (if any) above the plenum
- areas of missing insulation

Photographs:

- Camera should have a date stamp with the correct time and date
- Camera must have flash!
- Date stamp feature should be turned on.
- Your observation notes should cross-reference the times or photograph numbers
- Pictures should be taken of:
 - Underside of roof deck, looking down on top of ceiling tiles, top of roof.
- Extra pictures should be taken of insulation patterns:
 - Insulation removed by HVAC equipment, fan boxes etc.
 - Insulation missing by duct runs or piping runs.
 - Insulation coverage of light fixtures
 - Any place where insulation has been removed or damaged
 - A large area (such as an area re-tiled) missing insulation
- If a large area is missing insulation - discuss this with the site contact
 - Find out the history behind the missing insulation - was this due to a recent remodel? Document the story in your notes

June 11, 2001

MEMORANDUM

To: Effectiveness of Lay-in Insulation Advisory Group

From: Cathy Chappell, Jon McHugh

Re: Telephone Survey Procedure

The objective of the telephone survey is to investigate ceiling insulation characteristics in commercial buildings of various vintages. The deliverable for this task is 200 completed telephone surveys entered into the database.

Site Contacts

In order to conduct the telephone surveys, we had to obtain contact information of building owners and lessees. We used as our source F.W. Dodge data from 1995 to 2000, which had been cleaned for building-specific information only (i.e. data on parking structures and maintenance yards were removed).

We filtered the database for the following CEC climate zones: 3, 6, 10 and 12. We then selected all records for the following building types:

- office
- retail
- schools
- manufacturing
- assembly (religious buildings, civic centers, etc.)

With these restrictions, we identified 7,394 individual buildings. Within the database one building could have multiple contacts. We filtered the data further so that we kept only owner or lessee/franchisee contact names. This gave a target list of approximately 7,800 contact names.

From that list we pulled random samples of 400 names and supplied them to our subcontractor, SDV-ACCI, responsible for the telephone surveys. For each list of 400, we reviewed the contact information and removed the following type of entries:

- duplicate sites (this is different than multiple contacts for the same project)
- sites without phone numbers
- sites with insufficient addresses
- sites with insufficient building description

- sites that had received seismic upgrades or asbestos abatement
- warehouse-type retail sites that typically don't have t-bar ceilings
- other specific sites that typically don't have t-bar ceilings, such as school gymnasiums.

The surveyors were instructed to complete a minimum of 18 surveys in each of the four climate zones.

Phone Surveys

The telephone surveys were conducted with building owners, lessees, and building operators. We attempted to talk with the person most knowledgeable about the conditions of the ceiling and the space above it.

A copy of the phone survey instrument is included as Attachment 1. Attachment 2 contains the survey Fact Sheet which provides explanations and details to the surveyors.

The phone survey collects information on overall building characteristics such as building size, age, and construction. Ceiling specific information is collected including whether the ceiling has a t-bar ceiling, lay-in insulation over the t-bar, and recessed fluorescent light fixtures. Roof specific information is also collected including roofing material, roof deck construction, roof pitch, and roof insulation (if any).

The final survey question asks if the respondent will allow an on-site survey. If the respondent replies "yes" then the site is added to the potential on-site survey list. Once all of the telephone surveys are complete, we choose a sample of 70 sites from the list of potential on-sites. The 70 sites will be selected to adequately represent the four climate zones and the building types.

Characteristics of Buildings with Completed Surveys

This section summarizes the result of 201 completed surveys. As shown in Table 1, the buildings were fairly evenly divided across the four climate zones of interest. In addition the cross tabulation in this table by building type also indicates that the survey was well stratified with the more prevalent building types have greater representation in this sample (i.e. offices)

Bldg. Type	Building Type by CZ				Total
	3	6	10	12	
Assembly	1	3	2	1	7
Office	41	40	21	20	122
Retail	5	16	7	13	41
School	9	10	6	6	31
Total	56	69	36	40	201

Table 1 – Building type by climate zone

The data source for building contacts contained information on buildings that were built or remodeled within the past 5 years. However as illustrated in Table 2, most of the buildings in the sample buildings were over 5 years old and 29% were over 20 years old. Thus this sample will allow us to observe the ceiling characteristics of a range of building ages.

Bldg. Type	Building Age (Years)					Total
	<1	1-5	5-10	10-20	>20	
Assembly	0	2	0	1	4	7
Office	6	13	11	48	43	121
Retail	2	11	3	19	6	41
School	0	3	3	7	18	31
Total	8	29	17	75	71	200
1 office "NA"						

Table 2 – Building type by age

The distribution of building sizes in our sample is heavily weighted towards medium size buildings (10,000 to 50,000 sf, as shown in Table 3. Other than assembly, the buildings are well represented across size categories. As we see in the next section, this sample did not find many drop ceilings in assembly occupancies.

Bldg. Type	Building Size (Square Feet)					Total
	0-10,000	10,001-50,000	50,001-100,000	100,001-200,000	>200,000	
Assembly	2	3	2	0	0	7
Office	22	55	17	10	14	118
Retail	5	26	6	0	4	41
School	4	22	4	1	0	31
Total	33	106	29	11	18	197
4 offices' square footage was unknown						

Table 3 – Building type by size range

Characteristics of Buildings with Drop Ceilings

Since this study is ultimately interested in insulation characteristics above drop, or t-bar, ceiling systems, it is important to analyze the telephone survey results for those buildings that have drop ceilings. As shown in Table 4, the fraction of buildings that have drop ceilings varies by building type. Assembly spaces are often designed with ceiling finishes other than acoustic tile and are less likely to have drop ceilings than other building types. Schools are more likely to have drop ceilings than other building types.

Bldg. Type	# with Drop Ceiling	% with Drop Ceiling
Assembly	2	29%
Office	66	54%
Retail	23	56%
School	23	74%
Total	114	57%

Table 4 – Percent of buildings with drop ceilings by building type

One of the key questions to be answered by this project is “how effective is lay-in insulation in minimizing heat transfer across the roof/ceiling system?” Lay-in insulation is batt insulation that is draped over the top of acoustic ceiling tiles in t-bar ceilings. The results in Table 5 show that lay-in insulation is a relatively infrequent method of roof/ceiling insulation. Only 5% of the dropped ceilings in our sample were reported by the interview respondents as having lay-in insulation. This result reinforces the beliefs held by the t-bar ceiling manufacturers that lay-in insulation is infrequently used.

Bldg. Type	# with Drop Ceiling	# with Lay-in Insulation	% with lay-in insulation
Assembly	2	0	0%
Office	66	4	6%
Retail	23	1	4%
School	23	1	4%
Total	114	6	5%

Table 5 - Fraction of dropped ceilings with lay-in insulation

In Table 6 and Table 7 the distributions of building age and size category are shown for buildings with drop ceilings. The distributions across building type and building age for this subsample are very similar to those described in the previous section for the larger sample of all buildings. In our data, buildings with

drop ceilings do show a slightly higher concentration of older buildings than do the total set of buildings.

Bldg. Type	Building Age (Years)					Total
	<1	1-5	5-10	10-20	>20	
Assembly	0	0	0	0	2	2
Office	6	5	10	22	23	66
Retail	2	7	1	9	4	23
School	0	3	3	5	12	23
Total	8	15	14	36	41	114

Table 6 – Building type by age for buildings with drop ceilings

Bldg. Type	Building Size (Square Feet)					Total
	0-10,000	10,001-50,000	50,001-100,000	100,001-200,000	>200,000	
Assembly	0	1	1	0	0	2
Office	7	27	12	7	10	63
Retail	3	11	5	0	4	23
School	3	15	4	1	0	23
Total	13	54	22	8	14	111

3 offices' square footage was unknown

Table 7 – Building type by size range for buildings with drop ceilings

Skylights in Commercial Buildings

Of the 201 buildings in our sample, 52 or 26% had skylights. This is a substantially higher fraction of buildings with skylights than has been reported in the past. In Table 8, we compare the fractions of buildings containing skylights in our sample as well as in the NonResidential New Construction (NRNC) database. In the NRNC database, we find that skylights are more frequently found among participants in the Utilities' energy efficiency programs as compared to non-participants. This is not particularly surprising since skylights can be used to save energy and the building owner is participating in an energy efficiency program. For all building categories except retail the sample in this PIER lay-in insulation study has a greater frequency of buildings with skylights than those in the NRNC database.

The question for skylights is in a yes/no format so this does not give an indication of how many skylights are in each building. A consistent finding across all building types is that skylights in this insulation study sample are more likely to be in buildings that contain dropped ceilings. This result is particularly significant since the overall objective of this research program is to assist in the integration of skylights into the overall design of dropped ceilings.

Bldg. Type	NRNC Database		PIER Study Sample		
	Non Participant	Participant	Skylight in All Bldgs.	Fraction Dropped Ceilings	Skylight w/ Dropped Ceiling
Assembly	4%	11%	29%	29%	50%
Office	13%	14%	24%	54%	33%
Retail	8%	36%	27%	56%	43%
School	18%	22%	32%	74%	39%
Total	12%	21%	26%	57%	37%

Table 8 – Percent of buildings with skylights

We found skylights in 52 buildings overall. Of 114 buildings in our sample with drop ceilings, 42 had skylights.

Table 9 shows the distribution of the 42 buildings with both skylights and drop ceilings by building type and climate zone. The percentage of these buildings in each building type and climate zone is similar to the distribution of the entire set of buildings surveyed.

Bldg. Type	Building Type by CZ				Total
	3	6	10	12	
Assembly	0	0	0	1	1
Office	4	9	6	3	22
Retail	0	5	4	1	10
School	3	3	1	2	9
Total	7	17	11	7	42

Table 9 – Building type by climate zone for buildings with skylights and drop ceilings

The distribution of building ages and size categories across building types for these buildings with skylights and drop ceilings is shown in Table 10 and Table 11. The buildings are fairly evenly distributed across the age and size categories, although when compared with the distribution for all buildings, skylights seem to be slightly more prevalent in new buildings and larger buildings.

Bldg. Type	Building Age (Years)					Total
	<1	1-5	5-10	10-20	>20	
Assembly	0	0	0	0	1	1
Office	4	1	7	6	4	22
Retail	1	2	1	4	2	10
School	0	1	0	3	5	9
Total	5	4	8	13	12	42

Table 10 – Building type by age for buildings with skylights and drop ceilings

Bldg. Type	Building Size (Square Feet)					Total
	0-10,000	10,001-50,000	50,001-100,000	100,001-200,000	>200,000	
Assembly	0	0	1	0	0	1
Office	4	6	5	3	3	21
Retail	2	3	2	0	3	10
School	0	6	3	0	0	9
Total	6	15	11	3	6	41
1 office's square footage was unknown						

Table 11 – Building type by size range for buildings with skylights and drop ceilings

Conclusions

A phone survey of 200 assembly, office, retail and school building managers was conducted to understand the prevalence of drop ceilings, skylights and lay-in insulation. The survey results indicate the following:

- Over half of the buildings in the sample were reported to have dropped ceilings.
- Only 5% of the buildings with dropped ceilings were thought to have lay-in insulation.
- More skylights were reported in the sample than estimated from previous surveys
- The next task in this project is to conduct on-site surveys at 70 of the buildings. Table 12 shows the 70 selected buildings, which represent well the larger sample of 200 buildings.

Bldg. Type	Building Type by CZ				Total
	3	6	10	12	
Assembly	0	1	0	1	2
Office	12	9	11	7	39
Retail	0	4	3	7	14
School	4	5	3	3	15
Total	16	19	17	18	70

Table 12 – On-site survey building sample

Attachment 1 - Phone Survey

Call Record Sheet

Intrvw/Bldg. Code

Call #1

Interviewer: _____

Complete Date: _____

Interviewee: _____

Title: _____

Company: _____

Phone: _____

Which questions answered? _____ Attempt notes:



Call #2

Interviewer: _____

Complete Date: _____

Interviewee: _____

Title: _____

Company: _____

Phone: _____

Which questions answered? _____ Attempt notes:



Call #3

Interviewer: _____

Complete Date: _____

Interviewee: _____

Title: _____

Company: _____

Phone: _____

Which questions answered? _____ Attempt notes:



Call #4

Interviewer: _____

Complete Date: _____

Interviewee: _____

Title: _____

Company: _____

Phone: _____

Which questions answered? _____ Attempt notes:



Opening and Introductory Questions

Intrvw/Bldg. Code

[Introduce yourself.] “Hello. We are conducting a public interest study for the California Energy Commission as part of its Public Interest Energy Research program. Our part of the study is researching the energy efficiency of specific ceiling systems in commercial buildings in California. We would like to talk with you, as a building owner or facility manager, to discuss your building at: *[insert address]*

The call should take about ten minutes. Is this a good time?” *[If it is not a good time, schedule a call back time.]*

[Confirm identity of target interviewee, position and direct phone number in case there is a need to call back.]

Q1 Are you the owner or the owner’s representative for the building?

- Yes
- No (Get contact info) **Name:** _____
- Don’t Know (Get contact info) **Phone:** _____
- Refused (Thank and terminate)**

Q2a Our records show that this building is a *[insert occupancy type]*.

Is that correct?

- Yes
- No

If No, confirm actual occupancy type. If mixed, list only the primary type.

- Retail
- Office
- School
- Manufacturing
- Assembly (church, library, auditorium, etc.)
- Mixed Use _____ (types)
- Other (describe) _____

Q2b What is the top floor occupancy? _____

If they say "Residential," thank them and terminate the call.

Q3 How old is the building? [*Get either year built or approximate age.*]

- Year built (if known) _____
- Less than 1yr. old (*Skip to Q5*)
- 1 – 5 yrs. old
- 5 –10 yrs. old
- 10 –20 yrs. old
- > 20 yrs. old

Q4 Has this building been remodeled or renovated within the last 5 years?

Yes. If yes, in approximately what year?_

What was done? _____

No

Q5 How many floors are there in this building? _____

Q6 Approximately what is the total floor area of the building?
_____sq. ft.

Q7 Which of the following construction types best describes the exterior construction of this building:

- Wood frame
- Metal frame
- Concrete (either tilt-up or block)
- Other _____
- Don't know

Q8 Does the building have skylights over conditioned area?

Yes

No

Q9 Does the ceiling of the top floor have recessed fluorescent light fixtures.

Yes

No

Don't know

Technical Questions

[If the person you are speaking with doesn't know more than one of the questions on this page, ask for the name of someone who might know these answers. Then skip to the "Final Questions" section.]

Q10 Which of the following ceiling types best describes the ceiling on the top floor.

- Drop ceiling with acoustic tile (%)_____
- Sheet rock (%)_____ Don't know
- Other (Describe)_____ (%)_____

[If the building does not have acoustic tile, skip Q11-16; go to closing.]

Q11 Is the **roof** flat or sloped

- Flat (%)_____ Don't know
- Sloped (%)_____ (of roof area, not % of slope)

If both, check both boxes and list percentage of each.

Q12 Which best describes the roof deck? [List percentages if multiple.]

- Plywood
- Cement Don't know
- Metal/steel
- Other _____

Q13 Which best describes the roofing material? [List percentages if multiple.]

- Built-up tar
- Rubber membrane Don't know
- Composition shingles
- Other shingles/tile (e.g., cement tiles)
- Metal
- Other _____

Q14 Where is the ceiling or roof insulation located?

- Above the roof deck but under the roofing Don't know
- Below the roof deck (the underside of the roof deck)
- On top of the ceiling tiles
- Other _____
- No insulation

Q15 Does the HVAC system have a ducted return?

- Yes Don't know
- No

Final Questions

Q16 Could we send a surveyor to your facility to gather some direct-observation data?
(If they need more information, see discussion below)

- Yes
- No

*[If yes, let them know that the information you collected needs to be reviewed. Their building **may** then be part of a sample of sites that **will** be visited, based on a number of criteria. If they're selected, we'll call back later to schedule a convenient time.]*

To be filled out by interviewer:

Name of person giving this permission:

Title: _____

Is this person the owner or owner's representative?

- Yes
- No

Q17 If your building is selected for a site visit, we will be calling back in the next month or so. Would you prefer that we schedule the visit with you, or with someone else such as a site manager?

Owner

Site Manager

Scheduling Contact Name: _____

Title: _____ Phone: () _____

Closing:

Thank you, those are all the questions I have for you. If you have any questions please call me back at (916) _____.

Contingencies:

If prospect is unwilling to participate, do not press. Simply thank them for their time and hang up.

If they're concerned that we might be selling anything, assure them that this is not related to any sales effort; **no salesperson will call**. This is a research project.

If they have questions about who you are, say you are working for the Heschong Mahone Group on a research project for the California Energy Commission (CEC).

If they have are questions about HMG's role in this survey, explain that HMG is an energy research firm, and that the CEC is funding us to research the energy efficiency implications of lay-in insulation as a part of their efforts to learn how to make buildings more energy efficient and comfortable. If they have more questions, refer to Nehemiah Stone at HMG: (916) 962-7001.

FOR OTHER CONTINGENCIES, PLEASE SEE THE **PHONE SURVEY FAQ SHEET**.



**PIER INTEGRATED CEILING ELEMENT
LAY-IN INSULATION SCREENING TROUBLE SHEET**

Attachment 2 - Troubleshoot

This sheet is organized like the phone survey instrument, to allow you to address questions that arise as you conduct the survey. Although we have attempted to, we surely were not able to anticipate every situation or question that might come up. If there are any issues that seem to be "showstoppers" for the person you are interviewing, and you do not know the answer, please give us a call right away.

Introduction:

Answers to questions that might come up. If they ask:

Who are you? Tell them that you are working with the HESCHONG MAHONE GROUP, and that we are an energy research and consulting firm in the Sacramento area.

What are you selling? We are only doing research and we have nothing to sell. We are not associated with any product or manufacturer. No salesperson will call them related to this survey.

Who is in charge of this study? Or Who are you doing this study for? The California Energy Commission is funding the study and the HESCHONG MAHONE GROUP is performing and managing the study. If you need to speak to the project manager at HMG, I can give you his name and phone number. [Nehemiah Stone - (916) 962-7001]

Q1 Are you the owner or the owner's representative for the building?

Yes

No (Get contact info) Name: _____

Don't Know (Get contact info) Phone: _____

Refused (Thank and terminate)

Q2 Our records show that this building is a [insert occupancy type].

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lay-in insulation screening TROUBLE SHEET

We suggest that you fill this line in before placing the call. The occupancy types that are listed below are the only ones we intend to be calling. If the occupancy type is Residential, Amusement, Hotel, Medical, Service or Warehouse, they should not be on the list of buildings, and certainly should not be called. If you see Assembly or Education, these should be listed as "Assembly."

If you see "Government," start by assuming the occupancy is "office" and ask the question that way. If their answer indicates that it is some other kind of government building that could be described as one on the list below, use that type. If it is some kind of government building that is not on the list (e.g., Residential, Medical, Service, Warehouse), thank them and terminate the call.

Is that correct?

Yes

No

If No, confirm actual occupancy type. If mixed, check "Mixed use" and the primary type.

Retail

Office

School

Manufacturing

Assembly (church, library, auditorium, etc.)

Mixed Use

Other (describe) _____

List of occupancy types to be included, with descriptions and/or alternate names:

Retail: store, shopping mall, shopping center, grocery

Office: includes associated laboratories

School: grade school, high school, colleges, universities (not including dorms, theaters or gymnasiums)

Manufacturing: light manufacturing (e.g, computer assembly)

Assembly: includes religious/worship buildings, auditoriums, conference centers

Other: does not include any of the types below.

Mixed Use: not really a "type." If this is the answer, you will want to find out (a) what the predominant occupancy type is and (b) what the top floor is - but that is covered in the next question.

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- List of occupancies **not** to be included in the survey [If they respond with one of these, thank them and terminate the call.]:
- Industrial: heavy manufacturing (e.g. steel plant, auto assembly)
- Storage: warehouse ,storage facilities, garages, hangers
- Amusement: theaters, arcades
- Education: museums, libraries
- Hotel: hotels, motels
- Residential: houses, condominiums, high-rise residential, barracks, dormitories, townhouses, apartments, lodges, ranches, camps
- Medical: hospitals, clinics
- Service: service stations, gas stations, automobile shops
- _____

b) What is the top floor occupancy? _____

If they respond "residential," thank them and terminate the call.

Q3 How old is the building? [*Since it was first occupied. Get either year built or approximate age.*]

- Year built (if known) _____
- Less than 1yr. old (*Skip to Q5*)
- 1 – 5 yrs. old
- 5 –10 yrs. old
- 10 –20 yrs. old
- > 20 yrs. old

If they indicate that the building was built in stages (e.g., a major addition was done to an older existing structure), you want the original construction date for this question. For anything over twenty years, an approximate year is acceptable - they don't need to go find any documents to make sure their answer is more accurate than that.

Q4 Has this building been remodeled or renovated within the last 5 years?
(*If interviewee asks what qualifies as a "Yes," indicate that this means any work that changed the configuration of the walls or ceilings, involved major lighting changes, or otherwise required obtaining a building permit.*)

- Yes, approximate year? _____

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- No
- If the building has relatively short partitions and the only "remodeling" was moving the partitions, this does not qualify as remodeled. We are looking for changes that (a) would have required them to obtain a building permit, (b) effected a change-out of the ceiling lighting, or (c) may have had any other direct effect on the ceiling tiles and what's directly above them.

Q5 How many floors are there in this building? _____

If they ask, we are not interested in having them count the area on the roof of the building that is exposed or semi-exposed to the elements. We are interested in having them count all floors including basement floors and floors of parking.

If the building has "stepped" sides and they are wondering if they should count the floors near the top that are only 1/2 or less the size of lower floors, the answer is "yes." Count all floors regardless of varying sizes.

Q6 Approximately, what is the total floor area of the building? _____ sq. ft.

- If asked "what should I count?" tell them that you are interested in the total conditioned floor area of all floors listed above. This does not include parking areas, etc.

Q7 Which of the following construction types best describes this building:

- Wood frame
- Metal frame
- Concrete (either tilt-up or block)
- Other
- Don't know

If the interviewee answers "Other," try to get them to describe the construction materials. The supporting material, rather than the "skin" or finish material is what we are asking for here.

Q8 Does the building have skylights over conditioned area?

- Yes
- No

We are not interested in sunrooms.

Q9 Does the ceiling of the top floor have recessed fluorescent light fixtures?.

- Yes

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- No
- Don't know
- If they ask, "What do you mean by 'recessed fixtures'," you can tell them that the surface of recessed fixtures are on virtually the exact same plane as the ceiling tiles. "Surface mount" fixtures, on the other hand, "stick out" from the ceiling plane or appear to be attached onto the ceiling.
- _____ If the interviewee answers "Don't know" to more than one of these six questions (Q10 - Q15), you need to get another contact name and continue the survey with this new person. This new contact should be the building manager or maintenance manager or a similar person.

Q10 Which of the following ceiling types best describes the ceiling on the top floor?

- Drop ceiling with acoustic tile (%) _____
- Sheet rock (%) _____
- Other (%) _____
- (Describe)
- Don't know
- In some cases the "top floor" will actually be two or more floors (in the case of the 'stair-stepped' building design). We are interested in the ceiling structure and material of all of them. If they differ, then list the percentages of the total of all of them.
- If they ask, "How can I tell which it is," say that "drop-ceiling" acoustic tiles have uneven surfaces, typically with holes in them, and appear to be "framed" with painted metal rectangles. The ceiling tiles lay in the metal grid and can be easily pushed up to look above the ceiling. Acoustic tile ceilings could be applied directly to a framed and sheet-rocked ceiling, but won't have the metal "frames." These latter should be listed as "Sheet rock."
- The two ceiling types listed are clearly not all the materials that could be used, but we do not expect too many ceilings that aren't one or the other. If the ceiling appears to be something else, and they do not seem sure that the exposed material is applied over a sheetrock ceiling, then check "other," and write down how they describe the ceiling.

[If the building does not have acoustic tile, skip Q16 to closing.]

Q11 Is the **roof** flat or sloped?

- Flat (%) _____
- Sloped (%) _____
- Both [If both, get % of each]

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Don't know

*Make sure they understand this question is about the **roof**, not the ceiling. Also, we are not interested in the portion of "roof" that is directly above a parking facility.*

Q12 Which best describes the roof deck?

- Plywood
- Cement
- Metal/steel
- Other
- Don't know

This does not mean the roofing itself. The "deck" is also known as the sheathing. It is what you would find underneath if you tore off the roofing material. Generally, but not always, you can see the underside from the plenum or attic area.

Q13 Which best describes the roofing material?

- Built up tar
- Rubber membrane
- Composition tile
- Other tile (e.g., cement)
- Metal
- Other
- Don't know

There are actually a lot of other categories of flat roofing that we could have listed besides just "Built up tar" and "Rubber membrane." However, their answers need not be any more specific than this. Check off the one that seems closest to what they say.

"Composition tile" includes composition shingles and is a sloped roof material.

"Metal" includes any metal roofing product but does not include metal roof decks that are then covered with a membrane (other than paint).

If the building has more than one roof level and the roofing type varies between them, list each and the approximate percentages of each.

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Q14 Where is the ceiling or roof insulation located?

- On top of the roofing
- Above the roof deck but under the roofing
- Below the roof deck (the underside of the roof)
- On top of the ceiling tiles
- Other _____
- No insulation
- Don't know

Q15 Does the HVAC system have a ducted return?

- Yes
- No
- Don't know
- If they are not clear what a ducted return is you can ask them if there at least two registers in each room, and if the two look different as far as size and deflectors are concerned. If so, then they probably have ducted returns; if not, then they probably don't

Q16 Could we send a surveyor to your facility to gather some direct-observation data? *(If they need more information, see "Trouble Sheet.")*

- Yes
- No
-

*If yes, let them know that the information you collected needs to be reviewed to help us select buildings for site visits. Their building **may** then be part of a sample of sites that **will** be visited, based on a number of criteria. If they're selected, we'll call back later to schedule a convenient time.*

If your building is selected for a site visit, we will be calling back in the next month or so. Would you prefer that we schedule the visit with you or someone else, such as a site manager?

- Owner
- Site Manager

Site Manager Name: _____

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Title: _____ Phone: () _____

This information is for back-up purposes. It is not intended to be offered to interviewees unless asked.

The purpose of the on-site visit is to collect detailed information on the ceiling and the plenum (space between the ceiling and the roof). This information will be used to better understand commercial buildings in California. The on-site visit is non-intrusive and normally takes between 2 and 4 hours, depending upon the size and complexity of the building.]

If they ask what we mean by "non-obtrusive," let them know that someone will come in and look up in the space above the top floor ceiling tiles. They should not make any mess, and if they do, they will completely clean up before they leave. If there are people and/or desks in a general area that our site surveyors want to see, they will use specific locations that do not disrupt anyone working. Do not offer this except as a last resort, but if necessary, the site surveyors can make part of their inspection at a time when workers are not there (e.g., after work hours or on Saturday).

If the building manager (or whoever you are talking with) wants to be present the whole time the site surveyor is there, let them know that's not only NOT a problem but might prove very helpful to the surveyor.

If they seem to be concerned that the information collected might reflect badly on them or their building, assure them that no buildings visited, or even just included in the phone survey will be identified by name, address or any other traceable descriptors.

Tell them that if their building is selected as one of the sites to be surveyed, they will receive a small thank-you gift from the surveyor at the time of the visit (likely a fruit basket).

Thank you, those are all the questions I have for you. Do you have any questions? If you have any questions after our call please call me back at (916) _____.



Insulation Cost and Application Study
by
Mudit Saxena and Jon McHugh
Heschong Mahone Group
November 8, 2002

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Preface

The HESCHONG MAHONE GROUP has produced this report as part of the Integrated Design of Commercial Building Ceiling Systems research element of the *Integrated Energy Systems - Productivity and Buildings Science* energy research program managed by the New Buildings Institute. Cathy Higgins is the Program Director of this project for the New Buildings Institute.

The *Integrated Energy Systems - Productivity and Buildings Science* program is funded by the California Energy Commission under Public Interest Energy Research (PIER) contract No. 400-99-013. The PIER program is funded by California ratepayers through California's System Benefit Charges and is administered by the California Energy Commission (CEC). Donald J. Aumann is the CEC Programmatic Contact.

LEGAL NOTICE

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1. INTRODUCTION

The purpose of the Integrated Ceiling research is to develop a protocol for designing and specifying highly efficient ceilings that will integrate the effective placement of insulation, daylighting via toplighting, and daylight-responsive electric lighting controls. This protocol will help to reduce uncertainty regarding code compliance and construction costs, and will encourage energy efficient ceiling systems in commercial buildings.

The Integrated Ceiling research project consists of three related components:

1. Effectiveness of lay-in insulation research,
2. Comprehensive skylight testing, and
3. Culmination of these two components into an integrated ceiling system protocol for quality lighting (including daylight) and energy savings.

The research presented in this report supports the first component by presenting the cost calculations for different types of insulation for a prototypical commercial building used in the Effectiveness of Lay-in Insulation component. It also presents a summary of the information collected in telephone surveys conducted with architects.

1.2 Background

At least 60% of commercial building ceiling area is directly below a roof and therefore, the integration of building components and energy consuming systems in the ceiling system is a serious issue that impacts building energy use. The building components and energy consuming systems include dropped ceiling systems (T-bar and acoustical tile), electric lighting systems, skylights and daylighting systems, insulation and mechanical systems. Approximately 75% of new retail construction make use of dropped ceiling systems. Acoustic ceiling/lighting design affects fire protection, seismic safety, lighting, daylighting, insulation, mechanical systems and acoustics.

Electric lighting accounts for one third of all commercial electricity consumption¹, over one quarter of peak demand for commercial buildings and 11% of peak demand for all uses in California².

¹ Figure 2 - "End-Use Intensities" **Commercial Building Survey Report**, 1999, Pacific Gas and Electric Company, based on data collected on 1,000 commercial buildings in the CEUS (commercial end-use survey).

² 2001 Peak Demand by End-Use. Data provided by RE Rohrer, California Energy Commission.

1.3 Methodology

In this study we first conducted secondary research on ceiling and roof systems. We then interviewed architects to understand issues related to their preference in specifying insulation. We asked them about issues of longevity, first cost, ease of installation etc. for different types of insulation. This information gave us an understanding of how insulation is chosen and specified by architects for various projects.

We also contacted contractors to get the latest pricing information for both material and labor costs for the various types of insulation. We used this information to develop the cost-effectiveness options for various locations of insulation in the ceiling system.

2. RESEARCH FRAMEWORK

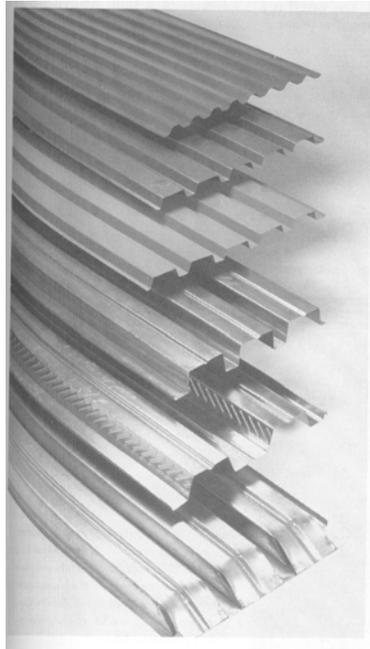
In order to make calculations of costs for the different types of insulation for a prototypical commercial building, it is first necessary to understand the types of roofs and insulation that are commonly used for such buildings. This section gives an overview of the types of roofs and insulation discussed later in the report.

2.1 Types of Roof Decks

Based on many years of building professional experience, we have observed that the majority of commercial building roofs are flat or low-slope and hence only those roof types have been considered in this research. The roofs can be classified according to the material used for the roof deck. The three types we have considered are metal deck, concrete deck, and plywood deck.

2.1.1 Metal Deck

Metals decks consist of a layer of corrugated rolled metal sheet that is typically 2 feet to 3 feet wide. Because the metal decking itself has structural capacity, it is possible to install it over metal purlins that are up to 4 feet apart. The corrugated metal sheets are lapped and a screw (or nail) with a washer is applied on the ridge of the corrugation to fasten it to the underlying structural members. Figure 1 shows examples of corrugated metal decking.

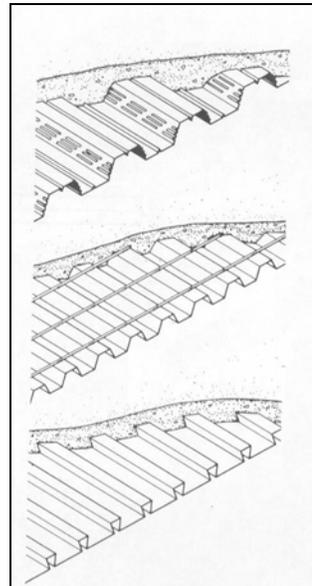


Source: Edward Allen

Figure 1: Examples of Corrugated Steel Decking

2.1.2 Concrete Deck

Concrete deck can be either a composite decking, or concrete roof slabs. In the composite decking, corrugated metal sheets are used as tensile reinforcing for the concrete which is poured on top of the metal as shown in Figure 2 and Figure 3. A concrete roof slab can be either a pre-cast plank, lifted into place, or the concrete is poured in place over removable plywood forms to make the slab in-situ with reinforcement. The concrete deck is supported over steel beams and used with steel frame buildings.



Source: Edward Allen

Figure 2: Examples of Composite Decking



Source: Edward Allen

Figure 3: Pouring Concrete Over Corrugated Metal for Composite Decking.

2.1.3 Plywood Deck

A plywood deck is made of panels of plywood supported over wooden or metal truss rafters on a wood framed building. The plywood deck is fastened to the framing using nails.



Source: Edward Allen

Figure 4: Plywood Decking on a Wood Framed Building

2.2 Types of Roof Membranes

Membranes are built over the roof decks for low-slope roofing and can be either built up roof membrane, single ply roof membrane, or fluid applied roof membrane. The first two types being the most commonly used are discussed below.

2.2.1 Built up Roof Membrane

A built up roof membrane is assembled in place from multiple layers of asphalt-impregnated felt imbedded in bitumen. These felt fibers may be cellulose, glass, or synthetic. Figure 5 shows two typical built-up roof constructions, as seen from above. The top diagram is a cut out view of a protected membrane roof over a poured concrete deck. The membrane is made from piles of felt overlapped. Rigid foam insulation boards are imbedded in hot asphalt over the membrane and blasted with stone aggregate. The bottom diagram shows a built up roof over corrugated metal roof deck with rigid insulation boards attached to a corrugated steel roof deck in two staggered layers. This provides a firm and smooth base for application of the membrane above.

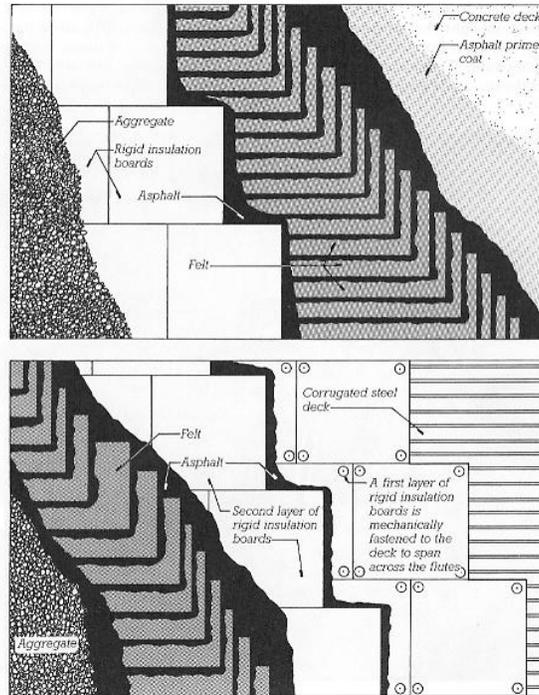


Figure 5: Two Typical Built Up Roof Constructions, Cut Away View As Seen From Above

2.2.2 Single-ply Roof Membrane

Single-ply membranes are made up of sheet materials that are applied to the roof in a single layer. As compared to built up membranes, they require less onsite labor, and they are usually more elastic and therefore less prone to cracking and tearing. They can be affixed to the roof by adhesives, by the weight of ballasts or by fasteners. Figure 6 shows roofers bonding a bitumen membrane to a concrete deck with a cold applied adhesive.



Figure 6: Roofers Bond a Bitumen Membrane to a Concrete Deck

2.3 Types of Ceiling

There are two primary ceiling types installed in commercial buildings: suspended acoustic and drywall.

2.3.1 Suspended Acoustic Ceiling

An acoustic ceiling is comprised of an inverted "T-bar" structure hung from the roof, which creates a grid. Acoustic tiles are installed in the grid to make a flat ceiling as shown in Figure 7.



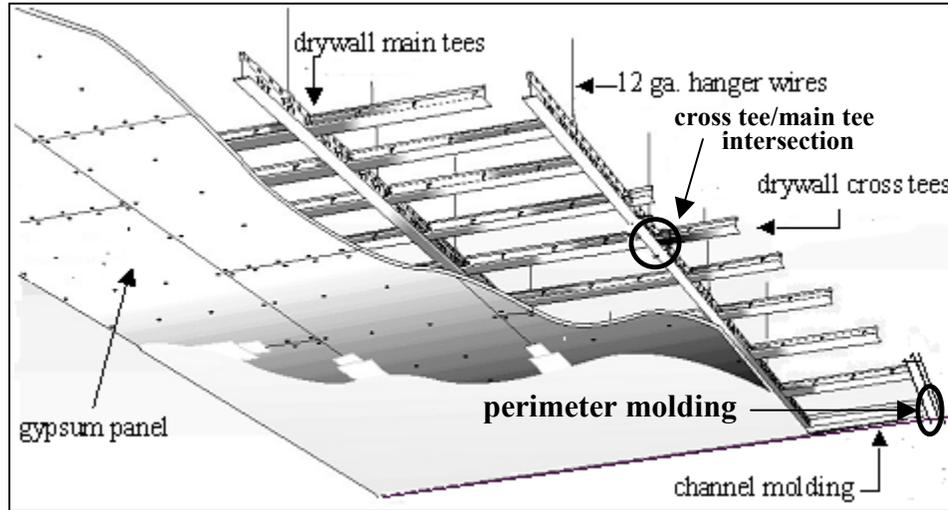
Source: Edward Allen

Figure 7: Acoustic Tile Ceiling

2.3.2 Drywall Ceiling

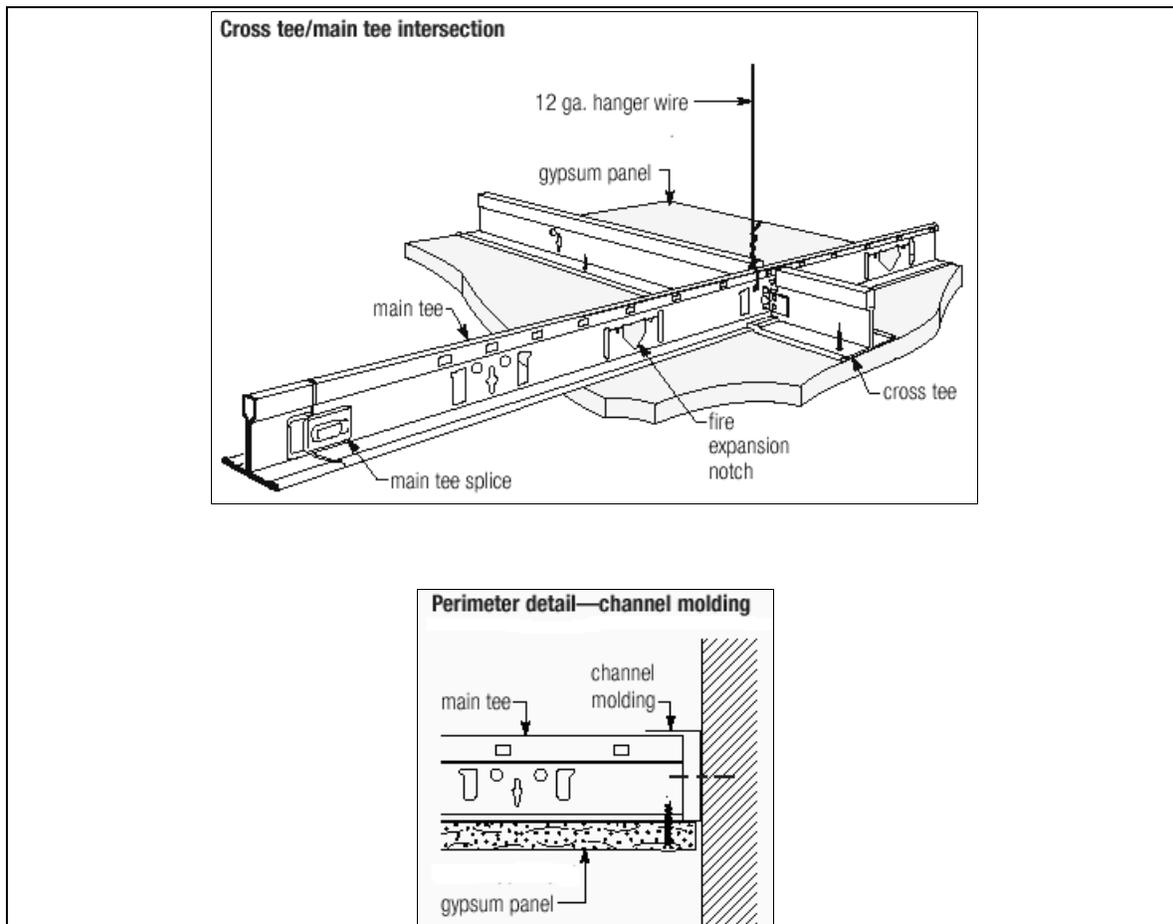
Drywall may be used instead of acoustic tiles in a suspended ceiling system. The most common system is the USG system. The USG system uses 24 gauge T-bar suspended from 12 gauge hanger wires. The drywall is screwed into the T-bar, taped, and then finished and textured. Figure 8 and Figure 9 below show a schematic diagram of the USG system.

Another, less common system is the Chicago-metallic system. A third system called the 'black iron and hatch system' is not in common use as it is more labor intensive.



Source: USG Drywall suspension system

Figure 8: USG System of Suspended Drywall Ceiling



Source: USG Drywall suspension system

Figure 9: Details of USG System of Suspended Drywall Ceiling

2.4 Types and Locations of Insulation

To insulate roofs and ceilings, various types of insulation can be specified in different locations either above or below the roof deck or on the acoustic ceiling. These can be classified under three situations:

- Rigid insulation above the roof deck,
- Non-rigid insulation below the roof deck, and
- Non-rigid (lay-in) insulation above acoustic tiles and t-bar ceilings.

Each is described in this section. These insulation situations are explored through a series of interviews, which are described later in this report.

2.4.1 Rigid Insulation Above Roof Deck

Insulation above roof deck is the most common configuration for membrane roofing. Rigid insulation materials are typically polystyrene or polyurethane foam boards, which are composed of closed-cell rigid foam of polystyrene or polyurethane. The strength of the board ranges from 15 PSI to 60 PSI. An R-20 board is about 4" thick. The insulation boards are usually adhered to the upper roof surface or fastened using screws and large sheet metal washers as shown in Figure 10.

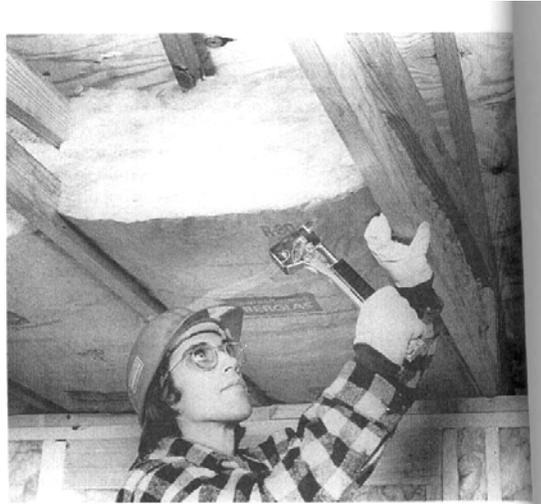


Source: Edward Allen

Figure 10: Screws and Large Sheet Metal Washers Attach Insulation to a Metal Deck

2.4.2 Non-rigid Insulation Below Roof Deck

The advantage of non-rigid insulation below the roof deck is that inexpensive nonstructural insulation may be used. Non-rigid insulation products are batts or blankets commonly made of fiberglass, glass wool, or rock wool. They are installed between framing members and held in place either by support mesh or by a facing stapled to the framing, as shown in Figure 11. The facing is either paper (Kraft faced), or foil (foil faced). An R-19 batt is usually 6" thick. A disadvantage is that the roof deck is subjected to greater thermal stress than when the insulation is installed above the roof deck.



(b)

Source: Edward Allen

Figure 11: Stapling Faced Batts Between Roof Trusses

2.4.3 Non-rigid Insulation Above Ceiling (Lay-in Insulation)

Dropped ceilings are often insulated by placing batts directly above the ceiling panels. Batts or blankets of non-rigid insulation are placed directly over the ceiling tiles as shown in Figure 12. The disadvantage to this approach is that the insulation is displaced when the ceiling panels are moved to gain access to the plenum space.



Figure 12: Non-rigid Insulation Above Ceiling Tiles

3. ARCHITECT INTERVIEWS

After conducting the preliminary research on types roof decks and insulation, we interviewed architects to understand their selection process. Specifically we wanted to know: why some types of insulation are preferred in certain projects; what are the issues related to installation of each type of insulation; what are the associated costs; and what other factors influence their decision such as requirements of the building codes and issues of longevity. A copy of the survey instrument is found in the appendix. We conducted the interviews during the spring and summer of 2002.

We first created a random list of architecture firms in the Sacramento area and screened the firms to be interviewed. From the list, we selected five firms on the basis of experience in designing commercial buildings. The architect in the firm with the most experience specifying insulation in commercial building projects was interviewed. As described in the previous section, we identified three variations of insulation type and location that we refer to as situations:

- Rigid insulation above the roof deck,
- Non-rigid insulation below the roof deck, and
- Non-rigid (lay-in) insulation above acoustic tiles and t-bar ceilings.

Later in this section, we report on the architects' ranking of these situations relative to various issues such as longevity, first cost and ease of installation. In the next section, we provide cost estimates for these situations.

3.1 Insulation Type

The interviewees were asked about the factors affecting the type of insulation they specify and the factors affecting the location of the insulation either rigid insulation over the deck, non-rigid insulation below the deck or non-rigid insulation above the acoustic ceiling. Based on the deck types described previously, we asked the architects questions about their choice of insulation by deck type.

3.1.1 Insulation for Metal and Concrete Decks

The interviewees were asked to identify the type and position of insulation they most commonly specify in projects with metal and concrete decks. They were also asked to give reasons for their choice.

Most of the interviewees said that rigid insulation over metal and concrete decks is preferred relative to non-rigid insulation under the deck. The most common reason given was the difficulty in installing non-rigid insulation under the deck. Interviewees did mention that in some cases they have used non-rigid insulation under metal and concrete decks, primarily because of requirements for fire rating

as insulation below the deck helps preserve the structural integrity of the roof deck in case of fire. Another reason given for using non-rigid insulation under decks was cost, since non-rigid insulation costs less than rigid. One interviewee stated that some building owners prefer non-rigid insulation as they have had a good experience with it previously, and insist on using it. Another interviewee made the point that when a roof is expected to have a lot of foot traffic or heavy equipment, insulation above the deck would have to be high density rigid insulation, which adds to the expense of the project. In such a situation, using insulation under the roof deck may prove to be more cost effective.

3.1.2 Insulation for Plywood Decks

The interviewees were asked to identify the type and position of insulation they most commonly specify in projects with plywood decks. Again, they were asked to give reasons for their choice.

In response to the question, the interviewees said that both rigid insulation above the deck and non-rigid insulation below the deck are used in projects with plywood decks. In general, the interviewees said that the preferred method is to install non-rigid insulation below the deck. Installing insulation onto the underside of a plywood deck is relatively easier to do than installing it on metal or concrete roof decks, which results in a lower cost. The cost of non-rigid insulation is also less than that of rigid insulation.

3.2 Insulation Location

The interviewees were asked when they specify non-rigid insulation laid in over t-bar acoustic ceilings (lay-in insulation), instead of insulation either above or below the roof deck. The interviewees mentioned various reasons for choosing to install insulation either rigid insulation at the roof or lay-in insulation at the ceiling. Most decisions are based on restrictions imposed by structural requirements or other project specific design constraints, as discussed below.

3.2.1 Lay-in Insulation

The architects interviewed cited the following advantages of lay-in insulation:

- It is advantageous to have insulation laid on top of acoustic ceilings to minimize transfer of sound through the ceiling in an office or conference room environment. This advantage is lost if the insulation is applied to the roof deck.
- If the roof height is high, and the space above the acoustic tiles does not require any kind of conditioning, then placing insulation on the ceiling limits the space that has to be conditioned. It is also preferred because lay-in insulation is typically cheaper than roof deck insulation. But in very cold climates, water pipes in an unconditioned plenum space may freeze. In such cases it is important not to specify lay-in insulation.

- In retrofit projects, lay-in insulation can be a relatively easy and inexpensive way to increase the R-value of an existing roof, compared to replacing insulation at the roof deck. Lay-in insulation is also easier to replace as compared to rigid insulation above the deck, although this is seldom done.

The architects interviewed cited the following disadvantages of lay-in insulation:

- The most commonly mentioned problem was related to maintaining the thermal integrity. The insulation gets displaced by people reaching into the plenum space for ducting and cabling work and then is often not correctly repositioned.
- Heat from light fixtures also gets trapped due to the insulation present around them. This results in overheating of the light fixture, possible premature failure of the light fixture and a potential fire hazard.
- If it is expected that the building will be occupied by multiple tenants other than the original occupants, then lay in insulation is not preferred. Typically the acoustic ceiling is replaced when new occupants move in, which makes the lay-in insulation is less cost-effective. In this case, insulation at the roof deck is preferred.

3.2.2 Rigid and Non-Rigid Insulation at the Roof Deck

The factors that affect the decision to specify rigid insulation were discussed with the interviewees.

Rigid insulation above the roof is favored when it is important to expose the structure of the roof such as trusses, joists etc. from below, for aesthetic reasons.

Rigid insulation is also commonly specified when the space below the deck is used as a return air plenum. In this case, non-rigid insulation below the deck (and/or above acoustic ceilings) cannot be used because fibers from the insulation would be introduced into the return air stream, which is prohibited by the mechanical code.

In some special cases, like clean rooms and rooms with computer equipment, non-rigid batt insulation is avoided, as the joints between them collect dust and need special treatment with taping.

Single ply membrane roofs, require rigid insulation to give the membrane some rigidity. Since rigid insulation above the deck serves the purposes of both insulating and rigidity, it is cost effective in this case as compared to using non-rigid insulation below the deck and providing rigidity using another material. When two layers of 1" rigid insulation are used, it gives an R-value of about 19. When a higher R-value is desired, for an existing roof with rigid insulation, non-rigid insulation is added below the deck because it is cost effective than adding additional layers above the deck.

The following advantages of installing insulation above the roof deck were given:

- The most common reason for choosing rigid insulation above the deck was aesthetics. By providing rigid insulation, especially on plywood decks, it is possible to expose the underside of the roof deck and joists to the space below.
- If the plenum space is to be used as a return air duct, then the mechanical code prohibits the use of non-rigid batt insulation over the ceiling or under the roof deck. In such cases, rigid insulation above the deck is typically used.

The following disadvantages of installing insulation above the roof deck were mentioned:

- Rigid insulation on the roof deck is typically more expensive than lay-in insulation.
- It is difficult to replace rigid insulation. A built-up or membrane roof would have to be ripped off to be able to access the rigid insulation. If there is a roof membrane failure and the rigid insulation is damaged by water, then a costly insulation replacement is required.
- Similarly, if the roofing needs to be replaced, usually the rigid insulation also has to be replaced due to the damage incurred on the insulation in the process of replacing the roofing.

3.3 Insulation Longevity

The interviewees were asked to rank the three insulation situations in terms of longevity. Three of the architect responded to the question. The other two felt that they could not provide a good estimate. The answers are presented in the matrix below, where A1 to A3 stand for the three architects who provided responses. In general, the respondents ranked under-deck, non-rigid insulation first in terms of longevity and lay-in insulation as last.

Insulation type and location ranking	A1	A2	A3
Rigid insulation on top of roof deck	2	1	2
Non-rigid insulation under roof deck	1	-	1
Lay-in insulation on top of acoustic tiles	3	2	3

Interviewee # A1 explained his ranking order and provided estimates of insulation life. Since there is less interaction with insulation under the deck, it tends to last longer, about 40 years. Insulation on the roof is more susceptible to leaks and repairs so it may not last as long, about 20 years. Lay-in insulation can get knocked off by someone accessing the plenum space. He estimated about 12 years before it needs reworking or replacing.

Interviewee # A2 also commented that lay-in insulation is often removed or shifted by people accessing the plenum for duct and ceiling work. He estimated that it would last for 10 years before needing to be replaced. Rigid insulation above the roof deck degrades due to people walking on the roof, water leakage and other exposure. He estimated the longevity of rigid insulation at 40 years. He refrained from giving an estimate for non-rigid insulation below the deck, because he did not have enough experience using it.

Interviewee # A3 provided the ranking order, but did not estimate longevity in years, due to lack of information on the issue.

3.4 First Cost

The interviewees were asked to rank the three insulation situations in terms of first cost, with lowest first cost was ranked as 1 and highest as 3. The answers are presented in a matrix below. Overall, respondents ranked lay-in insulation first in terms of lowest first cost.

Insulation type and location ranking	A1	A2	A3	A4	A5
Rigid insulation on top of roof deck	3	3	3	3	3
Non-rigid insulation under roof deck	2	1	1	2	2
Lay-in insulation on top of acoustic tiles	1	2	1	1	1

Interviewee # A3 said that in terms of material cost, non-rigid insulation was cheaper than rigid insulation when installed either below the deck or as lay-in insulation on top of acoustic tiles. He mentioned that there is no difference in labor cost for either case.

Interviewee # A2 said that for new construction lay-in insulation was costlier than non-rigid insulation below the roof, because installing insulation from below would require more labor. For existing buildings this is not the case.

Interviewee # A4 said that non-rigid insulation is cheaper than rigid insulation. For new construction, there is virtually no difference in labor cost for any of the three techniques. For existing buildings, labor cost for installing non-rigid insulation is less.

Interviewees # A1 and # A5 said that the cost of material as well as the cost of labor for rigid insulation above deck has the highest first cost, while lay-in insulation had the lowest.

3.5 Ease of Installation

The interviewees were asked to rank the three insulation situations in terms of ease of installation, with the easiest installation ranked as 1. Two of the Interviewees were of the opinion that there was not enough difference in terms of

ease of installation to provide a ranking. The answers of the three respondents are presented in a matrix below. In general, the respondents felt that lay-in insulation was the easiest to install.

Insulation type and location ranking	A1	A4	A5
Rigid insulation on top of roof deck	3	2	1
Non-rigid insulation under roof deck	2	2	3
Lay-in insulation on top of acoustic tiles	1	1	2

Interviewee # A4 gave rigid insulation above the deck and non-rigid insulation below the deck the same rank for retrofit work. He explained that he only prefers rigid insulation if the roof has to be redone anyway. Otherwise play-in insulation is his preferred choice.

3.6 Moisture Control

The interviewees were asked if they consider moisture control as an issue in the selection or placement of insulation.

Most interviewees said that moisture control is not an issue when deciding where the insulation is placed. However, they did say that a water membrane above the insulation should be provided when specifying rigid insulation above the deck.

One of the interviewees mentioned that moisture control is a consideration when deciding on insulation. He also mentioned that condensation within the insulation or the plywood deck is a structural as well as health concern.

3.7 Plenum Wall Insulation

We asked the interviewees if the extra cost of insulating plenum walls when opting for insulation at the roof deck is an issue of concern when deciding between roof deck insulation (above or below) and lay-in insulation. In general, interviewees have not considered this issue.

One interviewee stated that the cost of insulating the plenum walls was not significant enough to be of concern. Two interviewees said that they have not considered this issue in their decisions, but they agreed that it could be a significant point for projects with uncommonly high plenum heights. Two other interviewees said that they had never considered this as an issue in deciding the type of insulation to specify for the roof and offered no opinion.

Seismic code requirements in California for the thickness of tall concrete tilt-up walls ranges between 6¼ and 7¼ inches depending upon the seismic zone. In seismic zone 3 (much of the Central Valley) the typical thickness is 6-1¼ inches

and in seismic zone 4 (Bay Area and LA Basin) the typical thickness is 7¼ inches. Figure 13 shows a map of the seismic zones in California.¹

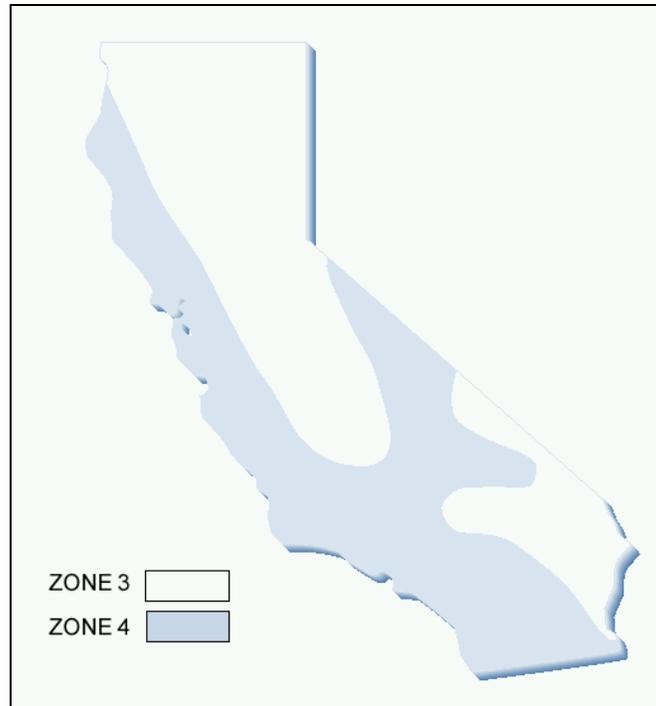


Figure 13: Statewide California Seismic Zone Map

For a building to comply with the Title 24 energy standards, either a minimum insulation R-Value or a maximum U-factor must be met. If the insulation R-value method is used, then the concrete tilt-up wall must have the required insulation. However, if the U-factor method is used, the concrete tilt-up wall² may meet the U-factor requirement, depending on wall thickness, without any additional insulation. However, the architects indicated that if walls are furred out to hide electrical wiring and plumbing, then the wall cavity is typically filled with insulation, even if it is not required. In subsequent calls to insulation contractors, we learned that it is likely that the insulation is provided even if it is not required by code.

¹ California Seismic Safety Commission. "The Homeowners Guide to Earthquake Safety," 1998 Edition. http://www.seismic.ca.gov/pub/CSSC_1997-01_HOG.pdf

² Including the inside and outside air films and an exterior finish, such as stucco.

4. COST ESTIMATES

To obtain cost data we utilized two sources. First, we interviewed contractors to get price quotes on several ceiling, roof and wall insulation options. Second we referenced the RS Means Data¹ as the industry standard to verify the pricing information provided by the contractors. The cost information is presented in Table 2 at the end of this section.

We averaged the data provided by the contractors. We then took an average of the RS Means data and the contractors' data. We used the resulting costs for the calculations for each of the construction options considered.

4.1 RS Means Data

The RS Means Data lookup tables provide a 20-city average cost for many typical construction materials and methods. To make a sound comparison with the cost data obtained from the contractors, we adjusted the data obtained from the lookup tables using RS Means city cost indexes, for cities in California. We applied an average of the city indexes for the cities of Sacramento, San Diego, Los Angeles, and San Jose, Stockton and Vallejo. The city index, shown in Table 1, is a percent ratio of the specific city's cost to the 20 city average cost of the same item at the same stated time period. The average for the three cities considered was 110.9.

Table 1: City Cost Indexes

City	Cost Index
Sacramento	109.8
Stockton	108.7
Vallejo	114.0
San Diego	105.4
Los Angeles	108.0
San Jose	120.0
Average	110.9

4.2 Contractor Calls

We interviewed sixteen commercial building contractors to get the latest pricing for the different components of the ceiling system. We contacted insulation

¹ RS Means Building Construction Cost Data, 15th Annual Edition, 2002 Western Edition.

contractors drywall contractors, acoustic ceiling contractors, and roofing contractors to get pricing on suspended drywall ceilings, suspended acoustic ceilings, lay-in insulation, rigid insulation and side wall insulation.

As with the architects, we created a random list of contractors in the Sacramento area. From that list, we conducted an initial screening to select those that had experience with commercial buildings. We called the contractors during the spring and summer of 2002.

The costs presented for each contractor includes material and labor cost as well as the contractors' overhead and profit. The contractors were asked to give a percent value of the labor cost they reported. This value is given in Table 2 as a percent value shown in the right portion of the cells. Some of the contractors refused to give out this information citing competitive reasons and hence are not reported.

In addition to specific cost information, we asked the contractors to describe the construction and installation methods used in their practice associated with the given price quotes. Clarifications for certain cost data were provided as described below.

4.2.1 Acoustic Ceilings

For suspended acoustic ceiling costs we obtained quotes for "typical" T-bar systems. These systems had 15/16" T-bar suspension system with 2' x 4' x 5/8" mineral fiber acoustic tiles. Two of the three price quotes were considerably lower than the RS Means values. The reason is that the RS Means cost is for a relatively expensive tile, whereas the quotes given by the contractors were for a plain flat white tile. The contractors agreed that their quotes were for a standard tile, but that more expensive tiles can be as much as \$10/sf.

4.2.2 Below Deck Insulation

Under metal roofs, non-rigid insulation is installed using "impaling pins" or "stick pins". The impaling pins are attached on the metal deck at the time of construction. Stick pins are adhered to the metal surface using an adhesive. The insulation is pushed into the impaling or stick pins and secured. For the below deck insulation, in survey 2 line wire is used to hold the un-faced insulation, cost of wire makes the cost of foil faced and un-faced insulation same. Foil faced insulation cannot be used below deck because of fire rating. FSK -25 (flame spread rating of 25) must be used. The survey quotes are for insulation with FSK-25.

4.2.3 Drywall Ceiling

Cost information was provided for two suspended drywall systems: 1) the USG system, and 2) the Chicago-metallic system. Four of the price quotes given were for the USG system (Surveys 2,3, 4 and 5). One price quote was provided for the Chicago system.

4.2.4 Side Wall Insulation

The method of installing insulation on a tilt-up concrete wall is to use “stick pins” on the concrete surface and then push the non-rigid insulation into the pin. Stick pins adhere to the surface of the concrete on its flat base, using an adhesive. The insulation is held on the pin. RS Means did not have price quotes for stick pins, therefore, the average cost is based on contractor information only.

4.3 Cost Information Summary

Table 2 below provides the cost data collected from RS Means and the contractors.

The first column identifies the system component and lists the specific items. Some items have more than one option for which cost data was collected, and are listed as separate line items. For the final cost calculations we chose only one of those options based on which one was most common as identified in our interviews.

The second column presents the average of the RS Means data and the contractor data for each item. The value in bold is the option that was used in the cost calculations. The third column provides the RS Means data for each item. Average costs from the contractor quotes are presented in the fourth column. The number of quotes for each option is listed in column five. Columns 6 through 10 give the individual costs quotes. The percent figure on the right of the columns is the fraction of the cost quoted that is labor. Some of the interviewees refused to reveal this information and are hence blank.

Table 2: Costs from RS Means and Contractors

	Average Cost	RS Means	Average from Quotes	No. of quotes	Quote 1*	Quote 2*	Quote 3*	Quote 4*	Quote 5*
Suspended Acoustic Ceiling									
Mineral Fiber on 15/16" T bar suspension 2' x 2' x 3/4" lay-in board	2.76 \$/SF	3.46 \$/SF	2.06 \$/SF	3	1.43 \$/SF 35%	3.00 \$/SF 40%	1.75 \$/SF 40%		
2' x 4' x 5/8" tile	1.85 \$/SF	2.34 \$/SF	1.36 \$/SF	3	1.35 \$/SF 35%	1.50 \$/SF 40%	1.23 \$/SF 40%		
Fiberglass ceiling board, 2' x 4' x 3/4", plane faced	2.64 \$/SF	3.19 \$/SF	2.09 \$/SF	3	1.65 \$/SF 35%	3.25 \$/SF 40%	1.38 \$/SF 40%		
Offices, 2' x 4' x 5/8"	1.99 \$/SF	2.21 \$/SF	1.77 \$/SF	3	1.57 \$/SF 35%	1.75 \$/SF 40%	1.98 \$/SF 40%		
Lay-in Insulation									
Fiberglass, Kraft faced batts or blankets 6" tk, R-19 23"wide	0.57 \$/SF	0.69 \$/SF	0.46 \$/SF	4	0.47 \$/SF 30%	0.43 \$/SF 35%	0.48 \$/SF	0.45 \$/SF 15%	
Foil faced R-19	0.68 \$/SF	0.74 \$/SF	0.61 \$/SF	4	0.60 \$/SF 30%	0.67 \$/SF 35%	0.52 \$/SF	0.65 \$/SF 15%	
Fiberglass, Kraft faced batts or blankets 3-1/2" tk, R-11 23"wide	0.43 \$/SF	0.52 \$/SF	0.34 \$/SF	4	0.37 \$/SF 30%	0.31 \$/SF 35%	0.33 \$/SF	0.35 \$/SF 15%	
Foil faced R-11	0.55 \$/SF	0.60 \$/SF	0.50 \$/SF	4	0.50 \$/SF 30%	0.56 \$/SF 35%	0.39 \$/SF	0.55 \$/SF 15%	
Below Deck Insulation									
Panelized 2x6 w/ 24 oc and 8' bay - stapled to wood	0.72 \$/SF	0.74 \$/SF	0.70 \$/SF	3	0.69 \$/SF	0.72 \$/SF	0.70 \$/SF 20%		
Fiberglass, Foil faced batts or blankets 6" tk, R-19 23"wide	0.62 \$/SF	0.70 \$/SF	0.55 \$/SF	3	0.43 \$/SF	0.72 \$/SF	0.50 \$/SF 20%		
Unfaced R-19									
Metal Deck using imaping pins									
Fiberglass, Foil faced batts or blankets 6" tk, R19 23"wide	0.97 \$/SF		0.97 \$/SF	3	0.79 \$/SF	1.17 \$/SF	0.95 \$/SF 25%		
Unfaced R-19	0.82 \$/SF		0.82 \$/SF	3	0.53 \$/SF	1.17 \$/SF	0.75 \$/SF 25%		
Fiberglass, Foil faced batts or blankets 3-1/2" tk, R-11 23"wide	0.86 \$/SF		0.86 \$/SF	3	0.67 \$/SF	1.07 \$/SF	0.85 \$/SF 25%		
Unfaced R-11	0.71 \$/SF		0.71 \$/SF	3	0.42 \$/SF	1.07 \$/SF	0.65 \$/SF 25%		
Concrete Slab - Ins attached with glue pins									
Fiberglass, Foil faced batts or blankets 6" tk, R-19 23"wide	1.10 \$/SF		1.10 \$/SF	3	1.17 \$/SF	1.17 \$/SF	0.95 \$/SF 25%		
Unfaced R-19	0.92 \$/SF		0.92 \$/SF	3	0.84 \$/SF	1.17 \$/SF	0.75 \$/SF 25%		
Above Deck Insulation									
25 PSI comp strength, 4" tk, R-20	1.70 \$/SF	1.70 \$/SF	1.70 \$/SF	3	1.55 \$/SF 50%	1.50 \$/SF 30%	2.04 \$/SF		
25 PSI, R-11	1.14 \$/SF	1.21 \$/SF	1.06 \$/SF	3	1.20 \$/SF 50%	0.82 \$/SF 30%	1.17 \$/SF		
IB System 100 - 3600 SF Project	3.60 \$/SF		3.60 \$/SF	1				3.60 \$/SF 38%	
Above 3600 SF	2.75 \$/SF		2.75 \$/SF	1				2.75 \$/SF 38%	
Dry Wall Ceiling									
Framing only using hanging t-bars - Sheetrock screwed on + taping and finishing	1.74 \$/SF	1.31 \$/SF	2.17 \$/SF	3	4.50 \$/SF		1.15 \$/SF	0.87 \$/SF	
	3.27 \$/SF	3.13 \$/SF	3.42 \$/SF	5	5.70 \$/SF	4.50 \$/SF	2.45 \$/SF	1.94 \$/SF	2.5 \$/SF
Framing using studs spanning across walls. Max is 16ft. span + taping and finishing	2.11 \$/SF		2.11 \$/SF	3	3.50 \$/SF		1.96 \$/SF	0.87 \$/SF	
	3.10 \$/SF		3.10 \$/SF	4	4.70 \$/SF		3.26 \$/SF	1.94 \$/SF	2.5 \$/SF
Side Wall Insulation									
For tilt up walls - Using stick pins or Impaling pins									
Fiberglass, unfaced batts or blankets 3-1/2" tk, R-11 23"wide	0.58 \$/SF		0.58 \$/SF	3	0.50 \$/SF	0.65 \$/SF	0.60 \$/SF		
Foil faced R-11	0.77 \$/SF		0.77 \$/SF	2	0.65 \$/SF	0.80 \$/SF	0.85 \$/SF		
Unfaced R-13	0.66 \$/SF		0.66 \$/SF	2	0.61 \$/SF	0.68 \$/SF	0.70 \$/SF		
Foil faced R-13	0.84 \$/SF		0.84 \$/SF	2	0.75 \$/SF	0.83 \$/SF	0.95 \$/SF		
For framed walls - insulation pushed in place									
Fiberglass, unfaced batts or blankets 3-1/2" tk, R-11 23"wide	0.40 \$/SF	0.50 \$/SF	0.30 \$/SF				0.30 \$/SF		
Foil faced R-11	0.56 \$/SF	0.60 \$/SF	0.53 \$/SF		0.49 \$/SF	0.50 \$/SF	0.60 \$/SF		
Unfaced R-13	0.47 \$/SF	0.54 \$/SF	0.40 \$/SF				0.40 \$/SF		
Foil faced R-13	0.61 \$/SF	0.62 \$/SF	0.60 \$/SF		0.56 \$/SF	0.53 \$/SF	0.70 \$/SF		
Using furring, R-11 non rigid unfaced insulation	0.56 \$/SF	0.43 \$/SF	0.70 \$/SF	2		0.73 \$/SF	0.68 \$/SF		
Using furring, R-13 non rigid unfaced insulation	0.60 \$/SF	0.43 \$/SF	0.78 \$/SF	2		0.83 \$/SF	0.73 \$/SF		

*Percent value on right is the fraction of the cost that is labor

4.4 Installed Cost Calculation

The average costs calculated in Table 2 for various insulation types and ceiling type were used to calculate total costs for eight construction options based on various insulation locations, as described in Table 3.

Table 3: Construction Options for Cost Calculations

Option	Description
1	Lay-in insulation on acoustic tiles
2	Lay-in insulation on drywall ceiling
3	Uninsulated plenum walls, non-rigid insulation under metal deck
4	Uninsulated plenum walls, rigid insulation above metal deck
5	Insulated concrete plenum walls, non-rigid insulation under metal deck
6	Insulated concrete plenum walls, rigid insulation above metal deck
7	Insulated plenum framed walls, non-rigid insulation above metal deck
8	Insulated plenum framed walls, rigid insulation above metal deck

To calculate the total installed cost of the roof/ceiling insulation system in a commercial building, we applied the various roof/ceiling insulation options to a prototypical building in several climate zones. The building is a 2, 000 sf. single-story office, with a ceiling height of 9’ and a flat roof. Above the ceiling, the plenum height is increased incrementally from 3’ up to 15’ in 3’ intervals.

Six climate zones were used for the roof insulation analysis - CTZ3, CTZ6, CTZ10, CTZ12 and CTZ14. The Title 24 standard prescriptive roof and wall R-values for each climate zone are given in Table 4. Since the insulation R-value requirements are the same for the last three climate zones, we present the final cost calculations as one result in the following section.

Table 4: Title 24 Prescriptive Roof/Ceiling and Wall R-values

Reqd. R-Value	CTZ 3	CTZ 6	CTZ 10	CTZ12	CTZ 14
Roof Insulation	19	11	19	19	19
Wall Insulation	11	11	13	13	13

4.5 Cost Estimates for Construction Options

The results of the detailed cost calculations, based on various plenum heights are presented in this section. Table 5 provides the results for Climate Zone 3. Table 6, provides the results for Climate Zone 4. Table 7 provides the results for Climate Zones 10, 12 and 14.

Table 5: Cost Calculations for Climate Zone 3

CZ 03								
Option	Components	Cost per Sq.ft (\$)	Cost (\$)	Plenum Height (ft.)				
				3'	6'	9'	12'	15'
1	Suspention system + Acoustic Tiles	\$1.85	3,699					
	Insulation R19	\$0.68	1,351					
	Total >>		5,050					
2	Suspention system + Drywall - taped and finished	\$3.27	6,543					
	Insulation R19	\$0.68	1,351					
	Total >>		7,895					
3	Non-rigid insulation R19 under metal deck	\$0.97	1,940					
	Acoustic Tiles	\$1.85	3,699					
	Total >>		5,639					
4	Rigid insulation R19 above metal deck	\$1.70	3,392					
	Acoustic Tiles	\$1.85	3,699					
	Total >>		7,091					
5	Plenum wall Insulation R11	\$0.77		414	828	1,242	1,656	2,070
	Non-rigid insulation R19 under metal deck	\$0.97	1,940	1,940	1,940	1,940	1,940	1,940
	Acoustic Tiles	\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
	Total >>			6,053	6,467	6,881	7,295	7,709
6	Plenum wall Insulation R11	\$0.77		414	828	1,242	1,656	2,070
	Rigid insulation R19 above metal deck	\$1.70	3,392	3,392	3,392	3,392	3,392	3,392
	Acoustic Tiles	\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
	Total >>			7,505	7,919	8,333	8,747	9,161
7	Plenum wall Insulation R11	\$0.56		305	609	914	1,219	1,523
	Non-rigid insulation R19 under metal deck	\$0.97	1,940	1,940	1,940	1,940	1,940	1,940
	Acoustic Tiles	\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
	Total >>			5,943	6,248	6,553	6,857	7,162
8	Plenum wall Insulation R11	\$0.56		305	609	914	1,219	1,523
	Rigid insulation R19 above metal deck	\$1.70	3,392	3,392	3,392	3,392	3,392	3,392
	Acoustic Tiles	\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
	Total >>			7,396	7,700	8,005	8,310	8,614

Table 6: Cost Calculations for Climate Zone 6

CZ 06								
Option	Components	Cost per Sq.ft (\$)	Cost (\$)	Plenum Height (ft.)				
				3'	6'	9'	12'	15'
1	Suspention system + Acoustic Tiles Insulation R11	\$1.85	3,699					
		\$0.55	1,097					
			4,796					
2	Suspention system + Drywall - taped and finished Insulation R11	\$3.27	6,543					
		\$0.55	1,097					
			7,641					
3	Non-rigid insulation R11 under metal deck Acoustic Tiles	\$0.86	1,727					
		\$1.85	3,699					
			5,425					
4	Rigid insulation R11 above metal deck Acoustic Tiles	\$1.14	2,271					
		\$1.85	3,699					
			5,970					
5	Plenum wall Insulation R11 Non-rigid insulation R11 under metal deck Acoustic Tiles	\$0.77		414	828	1,242	1,656	2,070
		\$0.86	1,727	1,727	1,727	1,727	1,727	1,727
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		5,839	6,253	6,667	7,081	7,495
6	Plenum wall Insulation R11 Rigid insulation R11 above metal deck Acoustic Tiles	\$0.77		414	828	1,242	1,656	2,070
		\$1.14	2,271	2,271	2,271	2,271	2,271	2,271
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		6,384	6,798	7,212	7,626	8,040
7	Plenum wall Insulation R11 Non-rigid insulation R11 under metal deck Acoustic Tiles	\$0.56		305	609	914	1,219	1,523
		\$0.86	1,727	1,727	1,727	1,727	1,727	1,727
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		5,730	6,035	6,339	6,644	6,949
8	Plenum wall Insulation R11 Rigid insulation R11 above metal deck Acoustic Tiles	\$0.56		305	609	914	1,219	1,523
		\$1.14	2,271	2,271	2,271	2,271	2,271	2,271
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		6,275	6,579	6,884	7,189	7,493

Table 7 Cost Calculations for Climate Zones 10, 12, 14

CZ 10, 12, 14								
Option	Components	Cost per Sq.ft (\$)	Cost (\$)	Plenum Height (ft.)				
				3'	6'	9'	12'	15'
1	Suspention system + Acoustic Tiles Insulation R19	\$1.85	3,699					
		\$0.68	1,351					
			5,050					
2	Suspention system + Drywall - taped and finished Insulation R19	\$3.27	6,543					
		\$0.68	1,351					
			7,895					
3	Non-rigid insulation R19 under metal deck Acoustic Tiles	\$0.97	1,940					
		\$1.85	3,699					
			5,639					
4	Rigid insulation R19 above metal deck Acoustic Tiles	\$1.70	3,392					
		\$1.85	3,699					
			7,091					
5	Plenum wall Insulation R13 Non-rigid insulation R19 under metal deck Acoustic Tiles	\$0.84		455	911	1,366	1,822	2,277
		\$0.97	1,940	1,940	1,940	1,940	1,940	1,940
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		6,094	6,549	7,005	7,460	7,916
6	Plenum wall Insulation R13 Rigid insulation R19 above metal deck Acoustic Tiles	\$0.84		455	911	1,366	1,822	2,277
		\$1.70	3,392	3,392	3,392	3,392	3,392	3,392
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		7,546	8,002	8,457	8,913	9,368
7	Plenum wall Insulation R13 Non-rigid insulation R19 under metal deck Acoustic Tiles	\$0.61		329	657	986	1,315	1,643
		\$0.97	1,940	1,940	1,940	1,940	1,940	1,940
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		5,967	6,296	6,625	6,953	7,282
8	Plenum wall Insulation R13 Rigid insulation R19 above metal deck Acoustic Tiles	\$0.61		329	657	986	1,315	1,643
		\$1.70	3,392	3,392	3,392	3,392	3,392	3,392
		\$1.85	3,699	3,699	3,699	3,699	3,699	3,699
		Total >>		7,420	7,748	8,077	8,406	8,734

Table 8 summarizes the results for each climate zone. Not surprisingly, the table shows that lay-in insulation on acoustic tiles is the least expensive across all climate zones. Non-rigid insulation under metal deck with uninsulated plenum walls is a close second in terms of lowest cost. The most expensive option is rigid insulation above metal deck with insulated plenum walls. Typically, across most climate zones, the second most expensive option is lay in insulation on a drywall ceiling.

Table 8: Summary of Costs for all Options and all Climate Zones

CZ 03

	<i>Lay-in insulation on Acoustic Tiles</i>	<i>Lay-in insulation on Drywall ceiling</i>	<i>Uninsulated plenum walls, non-rigid insulation under metal deck</i>	<i>Uninsulated plenum walls, rigid insulation above metal deck</i>	<i>Insulated plenum walls (conc), non-rigid insulation under metal deck</i>	<i>Insulated plenum walls (conc), rigid insulation above metal deck</i>	<i>Insulated plenum walls (framed), non-rigid insulation under metal deck</i>	<i>Insulated plenum walls (framed), rigid insulation above metal deck</i>
Plenum 3'	\$5,050	\$7,895	\$5,639	\$7,091	\$6,053	\$7,505	\$5,943	\$7,396
Plenum 6'	\$5,050	\$7,895	\$5,639	\$7,091	\$6,467	\$7,919	\$6,248	\$7,700
Plenum 9'	\$5,050	\$7,895	\$5,639	\$7,091	\$6,881	\$8,333	\$6,553	\$8,005
Plenum 12'	\$5,050	\$7,895	\$5,639	\$7,091	\$7,295	\$8,747	\$6,857	\$8,310
Plenum 15'	\$5,050	\$7,895	\$5,639	\$7,091	\$7,709	\$9,161	\$7,162	\$8,614

CZ 06

	<i>Lay-in insulation on Acoustic Tiles</i>	<i>Lay-in insulation on Drywall ceiling</i>	<i>Uninsulated plenum walls, non-rigid insulation under metal deck</i>	<i>Uninsulated plenum walls, rigid insulation above metal deck</i>	<i>Insulated plenum walls, non-rigid insulation under metal deck</i>	<i>Insulated plenum walls, rigid insulation above metal deck</i>	<i>Insulated plenum walls (framed), non-rigid insulation under metal deck</i>	<i>Insulated plenum walls (framed), rigid insulation above metal deck</i>
Plenum 3'	\$4,796	\$7,641	\$5,425	\$5,970	\$5,839	\$6,384	\$5,730	\$6,275
Plenum 6'	\$4,796	\$7,641	\$5,425	\$5,970	\$6,253	\$6,798	\$6,035	\$6,579
Plenum 9'	\$4,796	\$7,641	\$5,425	\$5,970	\$6,667	\$7,212	\$6,339	\$6,884
Plenum 12'	\$4,796	\$7,641	\$5,425	\$5,970	\$7,081	\$8,040	\$6,644	\$7,189
Plenum 15'	\$4,796	\$7,641	\$5,425	\$5,970	\$7,495	\$8,040	\$6,949	\$7,493

CZ 10, 12, 14

	<i>Lay-in insulation on Acoustic Tiles</i>	<i>Lay-in insulation on Drywall ceiling</i>	<i>Uninsulated plenum walls, non-rigid insulation under metal deck</i>	<i>Uninsulated plenum walls, rigid insulation above metal deck</i>	<i>Insulated plenum walls, non-rigid insulation under metal deck</i>	<i>Insulated plenum walls, rigid insulation above metal deck</i>	<i>Insulated plenum walls (framed), non-rigid insulation under metal deck</i>	<i>Insulated plenum walls (framed), rigid insulation above metal deck</i>
Plenum 3'	\$5,050	\$7,895	\$5,639	\$7,091	\$6,094	\$7,546	\$5,967	\$7,420
Plenum 6'	\$5,050	\$7,895	\$5,639	\$7,091	\$6,549	\$8,002	\$6,296	\$7,748
Plenum 9'	\$5,050	\$7,895	\$5,639	\$7,091	\$7,005	\$8,457	\$6,625	\$8,077
Plenum 12'	\$5,050	\$7,895	\$5,639	\$7,091	\$7,460	\$8,913	\$6,953	\$8,406
Plenum 15'	\$5,050	\$7,895	\$5,639	\$7,091	\$7,916	\$9,368	\$7,282	\$8,734

Appendix. A - Sample Survey Forms

A.1 Telephone Survey Form for Architects

Intrvw/Bldg. Code

Call #1

Interviewer: _____ Complete Date: _____

Interviewee: _____ Title: _____

Company: _____ Phone: _____

Which questions answered? _____ Attempt notes:

Call #2

Interviewer: _____ Complete Date: _____

Interviewee: _____ Title: _____

Company: _____ Phone: _____

Which questions answered? _____ Attempt notes:

Call #3

Interviewer: _____ Complete Date: _____

Interviewee: _____ Title: _____

Company: _____ Phone: _____

Which questions answered? _____ Attempt notes:

[Introduce yourself.] “Hello. We are conducting a public interest study for the California Energy Commission as part of its Public Interest Energy Research program. Our part of the study is researching the energy efficiency of specific ceiling systems in commercial buildings in California. We would like to talk with you, as a leading architect in this field about roof insulation.

The call should take about ten minutes. Is this a good time?" *[If it is not a good time, schedule a call back time.]*

[Confirm identity of target interviewee, position and direct phone number in case there is a need to call back.]

Q1. Out of the following choices, which type of buildings has your firm been involved with?

- Retail
- Schools
- Warehouses
- Institutional Buildings
- Manufacturing
- Health Care
- Offices
- Other: _____

Q2 In Roof construction, we most commonly see metal, plywood, or concrete roof decks. The roofing above this is either a built-up roof, a membrane roof, or a metal roof.

(a) Is there any combination of roof deck and roofing type that are incompatible? That is are there any combination of deck types and roofing types that you might never specify? As an example a metal roof with a concrete deck?

(b) I would like ask you where you specify the insulation for these roof types and why.

- A1. Metal deck with Membrane roofing
- B1. Metal deck with Built up roofing
- C1. Metal deck with metal roofing (?)

- A2. Plywood deck with Membrane roofing
- B2. Plywood deck with Built up roofing
- C2. Plywood deck with metal roofing

- A3. Concrete deck with Membrane roofing
- B3. Concrete deck with Built up roofing
- C3. Concrete deck with Metal roofing (?)

Q3 Is there any kind of roofing that you have used besides what we have discussed?

- Yes, Please explain:
- No

Q4 Under what conditions would you specify insulation laid in over t-bar acoustic ceilings? What applications or construction types would you use this?

Q5 Please rank the following in terms of longevity: rigid insulation on top of the deck, batt insulation under the roof deck and lay-in insulation on top of acoustic ceiling tiles. Please explain your selection

Q6 Please rank the following in terms of first cost: rigid insulation on top of the deck, batt insulation under the roof deck and lay-in insulation on top of acoustic ceiling tiles. Please explain your selection

Q7 Please rank the following in terms of ease of installation: rigid insulation on top of the deck, batt insulation under the roof deck and lay-in insulation on top of acoustic ceiling tiles.

Q8 Are there any factors that favor lay-in insulation against roof insulation? Such as acoustics, longevity, first cost, ease of installation, client preference or any other?

Closing:

Thank you, those are all the questions I have for you. If you have any questions please call me back at (916) 962 7001.

Contingencies:

If prospect is unwilling to participate, do not press. Simply thank them for their time and hang up.

If they're concerned that we might be selling anything, assure them that this is not related to any sales effort; **no salesperson will call**. This is a research project.

If they have questions about who you are, say you are working for the Heschong Mahone Group on a research project for the California Energy Commission (CEC).

If they have are questions about HMG's role in this survey, explain that HMG is an energy research firm, and that the CEC is funding us to research the energy efficiency implications of lay-in insulation as a part of their efforts to learn how to make buildings more energy efficient and comfortable. If they have more questions, refer to Nehemiah Stone at HMG: (916) 962-7001.

A.2 Telephone Survey Form for Contractors

Call #1

Interviewer: _____ Complete Date: _____

Interviewee: _____ Title: _____

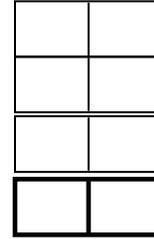
Company: _____ Phone: _____

Which questions answered? _____ Attempt notes:

		Total cost with labor	Fraction that is labor
Suspended Acoustic Ceiling			
<input type="checkbox"/> Mineral Fiber on 5/16" T bar suspension 2' x 2' x 3/4" lay-in board	3.12	\$/SF	
<input type="checkbox"/> 2' x 4' x 5/8" tile	2.11	\$/SF	
----- OR -----			
<input type="checkbox"/> Fiberglass ceiling board, 2' x 4' x 5/8", plane faced	1.99	\$/SF	
<input type="checkbox"/> Offices, 2' x 4' x 3/4"	2.88	\$/SF	
Laid-in Insulation / Insulation below			
<input type="checkbox"/> Fiberglass, Kraft faced batts or blankets 6" tk, R19 23"wide	0.62	\$/SF	
<input type="checkbox"/> Foil faced	0.67	\$/SF	
<input type="checkbox"/> Unfaced	0.63	\$/SF	
Above deck insulation			
<input type="checkbox"/> Extruded Polystyrene 15 PSI comp strength, 4" tk, R20	1.49	\$/SF	
<input type="checkbox"/> 25 PSI	1.53	\$/SF	
<input type="checkbox"/> 40 PSI	1.80	\$/SF	
<input type="checkbox"/> 60 PSI	2.05	\$/SF	
Dry Wall			
<input type="checkbox"/> Fire Resistant, no finish	0.60	\$/SF	
<input type="checkbox"/> On ceiling, fire resistant, taped and finished (level 4)	1.21	\$/SF	
<input type="checkbox"/> On ceiling, fire resistant, w/compound skim coat	1.45	\$/SF	

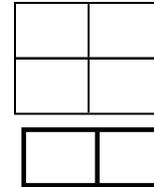
Side Wall Insulation

- Fiberglass, Kraft faced batts or blankets 6" tk, R11 23"wide 0.47 \$/SF
- Foil faced 0.54 \$/SF
- Unfaced 0.45 \$/SF



Side Wall Insulation (for CMU - poured in insulation)

- Poured Insulation Ceramic type (perlite) R3.2 per inch 3.57 \$/CF
- Vermiculite or perlite R 2.7 per inch 3.57 \$/CF



Others

Ceiling Suspension System

- Class A Suspension system 15/16" Tbars 2' x 4' grid 1.15 \$/SF
- Hanging wire, 12 ga, 4' long 10.55 \$/CSF
- Acoustic Tiles

Furring Strip

- Wood Strips 1" x 3" on wall, on wood 0.85 \$/LF