WHITE WOODS (WESTERN WOODS) (Surfaced dry or surfaced green)					
Select Structural No. 1 & Appearance No. 2 No. 3 Stud	2x4	1550 1300 1050 600 600	1630 1370 1100 630 630	1,100,000 1,100,000 1,000,000 900,000 900,000	Western Wood Products Association
Construction Standard Utility	2x4	775 425 200	810 450 210	900,000 900,000 900,000	(See notes 1 and 3)
Select Structural No. 1 & Appearance No. 2 No. 3 Stud	2x5 and wider	1300 1100 925 550 550	1370 1160 970 580 580	1,100,000 1,100,000 1,000,000 900,000 900,000	

1. When 2-inch lumber is manufactured at a maximum moisture content of 15% (grade marked MC-15) and used in a condition where the moisture content does not exceed 15%, the design values shown for "surfaced dry or surfaced green" lumber may be increased 8% for design value in bending "F_b", and 5% for modulus of elasticity "E".

2. National Lumber Grades Authority is the Canadian rules writing agency responsible for preparation, maintenance and dissemination of a uniform softwood lumber grading rule for all Canadian species.

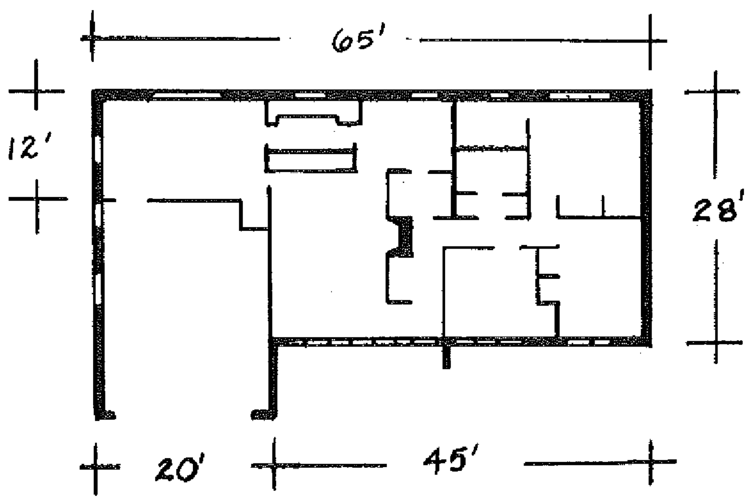
3. Design values for stud grade in 2x5 and wider size classifications apply to 5-inch and 6-inch widths only.

APPENDIX A

CHAPTER ILHR 22

DETERMINING THE LEVEL OF INSULATION

Two methods are outlined for determining the level of insulation, required by section ILHR 22.06 for non-electrically heated dwellings and by section ILHR 22.12 for electrically heated dwellings, using the following sample dwelling:



Sample dwelling: 1,500 square feet (186 lineal feet)

Gross wall area = 8.13 feet × 186 lineal feet = 1,512.18 square feet
Framed wall area = 1,301.69 square feet (20% framing, 80% cavity) (does not include box sill)
Wall window area = 172.67 square feet
Box sill area = 0.81 feet × 186 lineal feet = 150.66 square feet
Gross exposed foundation wall area = 124.62 square feet
Opaque exposed foundation area = 108.97 square feet
Basement window area = 15.65 square feet
Door area = 37.82 square feet
Ceiling area = 1,500 square feet (10% framing, 90% cavity)

METHOD I — COMPONENT METHOD

The component method outlined below can be used with minimum calculations for determining the acceptable level of insulation. The first example shows how to determine the level of insulation for non-electrically heated dwellings. The second example shows how to determine the level of insulation for electrically heated dwellings.

EXAMPLE I — NON-ELECTRICALLY HEATED DWELLING

Problem: Using the component method determine the level of insulation required for the 1,500 square foot dwelling.

Step 1: Determine the percentage window and door area in the wall above the foundation.

$$\text{Percent opening area} = \frac{\text{Window area} + \text{Door area}}{\text{Gross wall area} + \text{Box sill area}} \times 100\%$$

$$= \frac{172.67 \text{ sq. ft.} + 37.82 \text{ sq. ft.}}{1512.18 \text{ sq. ft.} + 150.66 \text{ sq. ft.}} \times 100\%$$

$$= \frac{210.49 \text{ sq. ft.}}{1,662.84 \text{ sq. ft.}} \times 100\% = 12.66\%$$

Step 2: Determine level of insulation required for the box sill and sidewalls for the given window and door area from Table A-1.

Using backed aluminum siding, the table shows that an R-11 batt with R-5.27 extruded polystyrene will allow up to 13% window and door area.

Step 3: Determine the percentage window area for the exposed foundation wall.

$$\text{Percent opening area} = \frac{\text{Window area}}{\text{Gross exposed foundation area}} \times 100\%$$

$$= \frac{15.65 \text{ sq. ft.}}{124.62 \text{ sq. ft.}} \times 100\% = 12.6\%$$

Step 4: Determine the amount of exposed foundation wall: If there is 8 inches of wall exposed and the wall height is 8 feet,

$$\text{Percent exposed wall} = \frac{8''/(12'' \text{ per foot})}{8'} \times 100\% = 8.3\%$$

Step 5: Refer to Table A-2 to determine the level of insulation required for the foundation.

Using the requirements for less than 25% exposed foundation wall, the table shows that R-5.27 insulation can be used for up to 24.8% double glazed windows.

Step 6: Select the level of insulation required for the ceiling from Table A-3.

TABLE A-1

WALL INSULATION GUIDE

(Based on U_o requirements above the foundation wall for non-electrically heated dwellings)

INSULATION TYPE	MAXIMUM PERCENT WINDOW AND DOOR AREA ALLOWABLE FOR INSULATION TYPE	
	U_o = .12	
	5/8 inch Plywood Siding	Backed Aluminum Siding
R-11 Batt	6.8	8.4
R-11 Batt, R-1.22 Fiberboard	8.7	9.9
R-11 Batt, R-5.27 Extruded Polystyrene	12.4	13.0
R-11 Batt, R-10.54 Extruded Polystyrene	14.9	15.3
R-13 Batt	8.3	9.8
R-13 Batt, R-1.22 Fiberboard	10.3	11.2
R-13 Batt, R-5.27 Extruded Polystyrene	13.1	13.6
R-13 Batt, R-10.54 Extruded Polystyrene	15.3	15.6
R-19 Batt	11.2	12.2
R-19 Batt, R-1.22 Fiberboard	12.3	13.1
R-19 Batt, R-5.27 Extruded Polystyrene	14.7	15.1
R-19 Batt, R-10.54 Extruded Polystyrene	16.3	16.6

Note: The following assumptions were used to derive this table:

1. Door area = 2% of wall and box sill area.
2. Doors are used with a U-value of 0.47.
3. Windows are used with a U-value of 0.56.
4. The insulation type is carried down through the box sill.

TABLE A-2

EXPOSED FOUNDATION INSULATION NON-ELECTRICALLY HEATED DWELLINGS

Foundation Exposure	Requirement	Insulation Type	Maximum Percent Window Area	
			Single glazed	Double glazed
Less than 25% of foundation exposed	U_o = .25	R-5.27	10.4	24.8
		R-11 batt	15.5	34.2
		Multi-cell insul. block (R-12.06)	16.0	35.0
More than 25% of foundation exposed	U_o = .13	R-11 batt	3.9	8.7
		R-13 batt	4.8	10.6
		Multi-cell insul. block (R-12.06)	4.5	9.9
	U_o = .12	R-11 batt	3.0	6.7
		R-13 batt	3.9	8.5
		Multi-cell insul. block (R-12.06)	3.5	7.8

TABLE A-3

INSULATION LEVELS REQUIRED TO MEET CEILING U VALUES FOR NON-ELECTRICALLY HEATED DWELLINGS

U_0 Value	Insulation	R-Value Required	
		In Cavity	Over Framing
.029	Fiber glass batt	R-38	R-19
	Fiber glass blown	13.6 in. (R-34)	8.1 in. (R-20)
	Rock wool	10.9 in. (R-33)	5.4 in. (R-16)
	Cellulose	9.5 in. (R-35)	4.0 in. (R-15)

Note: The following assumptions are used:

1. Fiber glass blown = R-2.5 per inch
2. Rock wool = R-3.0 per inch
3. Cellulose = R-3.7 per inch

EXAMPLE II — ELECTRICALLY HEATED DWELLING

OPAQUE WALL AND BOX SILL:

Problem: Using the component method, determine the level of insulation required for the walls and box sill of the 1500 square foot dwelling.

Solution #1: Using Tables E-1 and E-2.

Step 1: Determine the composition of the above grade wall by calculating the percent of the area which is made up by windows, doors and foundation.

$$\text{Percent window area} = \frac{\text{Window area} + \text{foundation window area}}{\text{Total above grade wall area}} \times 100\%$$

Total above grade wall area =

Gross wall area + box sill area + Gross exposed foundation area

(Note that the total above grade wall area includes the exposed foundation wall area. However, if the basement or crawl space ceiling is insulated instead of the foundation, the exposed foundation area is set equal to zero because it is not a part of the thermal envelope.)

Total above grade wall area = 1512.18 sq. ft. + 150.66 sq. ft. + 124.62 sq. ft. = 1787.46 sq. ft.

$$\%\ \text{Window area} = \frac{172.67 \text{ sq. ft.} + 15.65 \text{ sq. ft.}}{1787.46 \text{ sq. ft.}} \times 100\% = 10.53\%$$

The %'s of other components are calculated in a similar manner:

$$\%\ \text{Door area} = \frac{\text{door area}}{\text{Total wall area}} \times 100\% = \frac{37.82 \text{ sq. ft.}}{1787.46 \text{ sq. ft.}} \times 100\% = 2.12\%$$

$$\%\ \text{Opaque foundation area} = \frac{\text{opaque foundation area}}{\text{total wall area}} \times 100\%$$

$$= \frac{108.97 \text{ sq. ft.}}{1787.46 \text{ sq. ft.}} \times 100\% = 6.10\%$$

$$\% \text{ Frame wall \& box sill area} = \frac{\text{frame wall area} + \text{box sill area}}{\text{total wall area}} \times 100\%$$

$$= \frac{1301.69 \text{ sq. ft.} + 150.66}{1787.46 \text{ sq. ft.}} \times 100\% = 81.25\%$$

Step #2: Use Tables E-1 to determine the opaque wall and boxsill U-value and Table E-2 to determine the insulation levels for electrically heated dwellings.

Table E-1 was formulated with the following assumptions:

— The doors have R-values of at least R-8 and form 2% or less of the above-foundation wall.

$$\frac{\text{door area}}{\text{gross wall area} + \text{box sill area}} \times 100\%, \text{ in this case} =$$

$$\frac{37.82}{1512.18 + 150.66} \times 100\% = 2\%$$

— Windows with an R-value of at least 2.7 (triple glazed) are used, including the foundation windows.

— The exposed foundation area is insulated to a level of R-10.54.

If these assumptions are not valid for your case, calculate the required U-value as shown in solution #2.

For this example:

% Opaque foundation area = 6%

% Window area = 11%

From Table E-1, the maximum above-foundation wall U-value = 0.044 Btu/hr. sq. ft. °F.

For compliance, insulation materials and framing type should be used which produce a U-value which is less than or equal to the maximum U-value determined from Table E-1, as above. Table E-2 shows the U-values obtainable from different insulation material combinations and framing types.

TABLE E-1

MAXIMUM ABOVE-FOUNDATION WALL U-VALUES FOR ELECTRICALLY HEATED HOMES

PERCENT WINDOW AREA

		5	6	7	8	9	10	11	12	13	14	15	16
	0	.065	.062	.059	.056	.053	.050	.046	.043	.040	.036	.032	.029
	5	.065	.061	.058	.055	.051	.048	.044	.041	.037	.033	.029	.025
	6	.064	.061	.058	.055	.051	.048	.044	.040	.037	.033	.029	.025
PERCENT	7	.064	.061	.058	.054	.051	.047	.044	.040	.036	.032	.029	
	8	.064	.061	.057	.054	.050	.047	.043	.039	.035	.031	.027	
	9	.064	.061	.057	.054	.050	.046	.043	.039	.035	.031	.027	
OPAQUE	10	.064	.060	.057	.053	.050	.046	.042	.038	.034	.030	.026	
	11	.064	.060	.057	.053	.049	.046	.042	.038	.034	.030	.025	
	12	.063	.060	.056	.053	.049	.045	.041	.037	.033	.029	.025	
FOUNDA-	13	.063	.060	.056	.052	.049	.045	.041	.037	.033	.028		
	14	.063	.059	.056	.052	.048	.044	.040	.036	.032	.027		
	15	.063	.059	.055	.052	.048	.044	.040	.036	.031	.027		
TION	16	.063	.059	.055	.051	.047	.043	.039	.035	.031	.026		
	17	.062	.059	.055	.051	.047	.043	.039	.034	.030	.025		
	18	.062	.058	.055	.051	.047	.042	.038	.034	.029			
AREA	19	.062	.058	.054	.050	.046	.042	.037	.033	.028			
	20	.062	.058	.054	.050	.046	.041	.037	.032	.028			
	21	.061	.057	.053	.049	.045	.041	.036	.032	.027			
	22	.061	.057	.053	.049	.045	.040	.036	.031	.026			
	23	.061	.057	.053	.048	.044	.040	.035	.030	.025			
	24	.061	.057	.052	.048	.044	.039	.034	.029				
	25	.060	.056	.052	.048	.043	.038	.034	.029				

TABLE E-2

FRAME WALL & BOX SILL U-VALUES FROM DIFFERENT BUILDING MATERIALS AND METHODS

Insulation Type	2 × 4 FRAMING 16" O.C.[1]	2 × 6 FRAMING 16" O.C.	2 × 6 FRAMING 24" O.C.[2]	Double 2 × 4 or 2 × 8 FRAMING 24" O.C.
R-11 Batt	0.091			
R-11 Batt, R1.22 Fiberboard	0.081			
R-11 Batt, R5.27 Polystyrene	0.060			
R-11 Batt, R10.54 Polystyrene	0.045			
R-11 Batt, R7.21 Isocyanurate	0.054			
R-11 Batt, R14.4 Isocyanurate	0.038			
R-13 Batt	0.083			
R-13 Batt, R1.22 Fiberboard	0.074			
R-13 Batt, R5.27 Polystyrene	0.056			
R-13 Batt, R10.54 Polystyrene	0.043			
R-13 Batt, R7.21 Isocyanurate	0.050			
R-13 Batt, R14.4 Isocyanurate	0.036			
R-19 Batt		0.060	0.058	0.056
R-19 Batt, R1.22 Fiberboard		0.055	0.053	0.052
R-19 Batt, R5.27 Polystyrene		0.044	0.043	0.042
R-19 Batt, R10.54 Polystyrene		0.036	0.035	0.034
R-19 Batt, R7.21 Isocyanurate		0.040	0.039	0.039
R-19 Batt, R14.4 Isocyanurate		0.031	0.030	0.030
Two R-11 Batts				0.053
Two R-11 Batts, R1.22 Fiberboard				0.049
Two R-11 Batts, R5.27 Polystyrene				0.040
Two R-11 Batts, R10.54 Polystyrene				0.033
Two R-11 Batts, R7.21 Isocyanurate				0.037
Two R-11 Batts, R14.4 Isocyanurate				0.029
Two R-13 Batts				0.048
Two R-13 Batts, R1.22 Fiberboard				0.045
Two R-13 Batts, R5.27 Polystyrene				0.037
Two R-13 Batts, R10.54 Polystyrene				0.030
Two R-13 Batts, R7.21 Isocyanurate				0.034
Two R-13 Batts, R14.4 Isocyanurate				0.027

[1] Assumes 20% framing, 80% cavity.

[2] Assumes 17% framing, 83% cavity.

Solution #2: To calculate the required wall U-value without using Tables E-1 and E-2, use the method outlined below:

Step 1: Calculate the above grade wall composition as illustrated in Step 1 of Solution #1.

% Window area = 10.53%

% Door area = 2.12%

% Opaque foundation area = 6.10%

% Opaque wall & box sill area = 82.25%

Step 2: Use the following formula to calculate the maximum allowable U-value for the opaque wall and box sill.

$$\frac{U_o - (U_w \times \%w) - (U_d \times \%d) - (U_f \times \%f)}{\%_{wall}} = U_{wall}$$

Where:

U_O	= Required overall above grade wall U-value, use 0.080 for an electrically heated home
U_W	= The U-value of the windows (= 1/R-value)
$\%_W$	= The fraction of window area calculated in Step 1
U_d	= The U-value of the doors (= 1/R-value)
$\%_d$	= The fraction of door area calculated in Step 1
U_f	= The U-value of the insulated foundation
$\%_f$	= The fraction of exposed foundation calculated in Step 1
$\%_{wall}$	= The fraction of opaque wall and box sill area as calculated in Step 1
U_{wall}	= The maximum U-value of the opaque wall and box sill to be calculated

In our example:

The window R-value = R-2.78	U = 1/2.78 = 0.341
The door R-value = R-8.85	U = 1/8.85 = 0.113
The foundation R-value = R-12.4	U = 1/12.4 = 0.080

$$U_{wall} = \frac{0.080-(0.341 \times 0.1053)-(0.113 \times 0.0212)-(0.080 \times 0.0610)}{0.8225} = 0.045$$

In this case, the maximum U-value of the opaque wall and box sill is 0.045 Btu/hr. sq. ft. °F. For compliance, the insulation which is installed in the wall and box sill must provide a U-value which is less than or equal to 0.045. Table E-2 shows the U-values obtainable from different insulation materials and framing types.

CEILING:

Problem: Using the component method, determine the level of insulation required for the ceiling of the 1500 sq. ft. dwelling.

Solution #1: Use Table E-3

Table E-3 gives the amount of installed insulation which would be necessary to achieve a required U-value in the ceiling or attic.

Table E-3 was formulated with the following assumptions:

— The loose fill insulation, if used, is installed to provide the following R-values:

Cellulose	R = 3.7/in
Expanded pearlite	R = 2.7/in
Mineral Fiber (rock, slag, or glass)	R = 3.3/in
Polystyrene beads	R = 2.9/in
Fiber glass, blown	R = 2.5/in

— The insulated area is 90% cavity and 10% 2 × 6 framing

— There are no skylights in the ceiling/attic assembly

— The R-value of the ceiling finish materials plus air films is R-1.2

— The attic hatch is insulated to the same level as the rest of the attic floor, if it is a part of the thermal envelope.

If these assumptions are not valid for your case, calculate the required U-value as shown in solution #2.

TABLE E-3

INSULATION LEVELS REQUIRED TO MEET CEILING U_0 VALUES

Dwelling Fuel Type	U_0	Insulation Type	Amount Required In Cavity Depth (R-Value)
Electrically Heated	0.020	Fiber glass Batts	R-54
		Cellulose	14.1 in. (R-52)
		Expanded Pearlite	18.6 in. (R-50)
		Mineral Fiber	15.6 in. (R-51)
		Polystyrene Beads	17.5 in. (R-52)
		Blown Fiber glass	20.0 in. (R-50)

Solution #2: To calculate the required ceiling insulation level for ceiling/attic assemblies, use the following method.

Step 1: Calculate the required U-value for the attic floor, U_F, with the following formula.

$$U_F = \frac{UoAo - UsAs - Uh\,Ah}{A_F}$$

Where:

U_F = The required U-value for the attic floor

U_0 = The overall U-value set by the code, use 0.020 for an electrically heated dwelling

A_0 = The overall attic/ceiling area including the attic floor, any skylights and the attic hatch or access panel

U_s = The U-value of the skylights including the frame

A_S = The area of skylights, including the frame (if there are no skylights, set equal to zero)

U_h = The U-value of the attic hatch or access panel

A_h = The area of the attic hatch or access panel (If the hatch is to be insulated to the same level as the attic floor, add the area to the floor area, A_F, and set A_h equal to zero. If the attic hatch or access panel is not a part of the thermal envelope, set A_h equal to zero.)

A_F = The area of the insulated attic floor, equal to the overall attic/ceiling area minus the attic hatch and skylight areas, if any.

Example: For the attic of an electrically heated dwelling with an overall attic area of 1500 sq. ft. The attic hatch is 14" × 24" and is to be insulated with two R-19 fiber glass batts, the rest of the attic is to be insulated with blown mineral fiber with an R-value of 3.3/inch. There are two skylights, each 6 square feet with R-values of 1.8.

The R-value of the attic hatch is the sum of the R-values of the batts plus R-2 for the finish materials and air films.

$R = 19 + 19 + 2 = 40$

The U-value of the hatch is $U_h = 1/40 = 0.025$

The U-value of the skylights $U_S = 1/1.8 = 0.56$

The area of the hatch $= 2 \text{ ft} \times 1.17 \text{ ft} = 2.3$ sq. ft.

The area of the skylights is 12 square feet

The area of the floor is $1500 - 12 - 2.3 = 1486$ sq. ft.

$$U_F = \frac{(0.020)(1500) - (0.56)(12) - (0.025)(2.3)}{1486} = 0.0156$$

Step #2: To calculate the amount of insulation needed over the framing and cavity areas, d, of the attic floor use the following formula:

$$d = \frac{1}{U_F\,(R/in)} - \frac{(RW/in)\ h}{(\%C)(RW/in) + (\%W)(R/in)} - \frac{Rfin + h}{(R/in)}$$

Where:

d	=	depth of insulation at cavity in inches
U_F	=	required U-value of floor calculated in Step #1
R/in	=	R-value per inch of insulating material obtained from manufacturer or Table A-4
h	=	height of framing, 5-1/2" for 2 × 6 framing or 7-1/4" for 2 × 8 framing, for example.
%C	=	fraction of floor which is cavity (usually assume 0.9)
%W	=	fraction of floor which is framing (usually assume 0.1)

RW/in = R-value per inch of wood framing (usually assume 1.25 R/inch)

R_{fin} = R-value of interior ceiling finish materials, including air films (usually assume R-1.2)

$$d = \frac{1}{(0.0156)(3.3)} - \frac{(1.25)(5.5)}{(0.9)(1.25)+(0.1)(3.3)} - \frac{1.2}{3.3} + 5.5 = 19.59 \text{ inches}$$

The floor of the attic is to be covered with insulation so that the depth in the cavities is equal to 19.59 inches.

METHOD II — SYSTEM DESIGN METHOD

The system design method is the more complex method of determining the level of insulation required by the code. This procedure may be used when it becomes necessary to combine various materials to comply with the code. If the window area is increased and the same wall insulation is used, the wall section will not meet the requirements of section ILHR 22.06 or 22.12 (1) (6), but the system design method can be used by adding extra insulation elsewhere.

Problem: Using the system design method, increase the opening area to 15% and determine compliance by adding extra insulation to the walls and ceiling.

Step 1: Determine the inside and outside design temperatures from Tables 22.04-A or 22.10A, and 22.04-B.

Inside temperature = 70° F
Outside temperature = -20° F
$\Delta T = T_{inside} - T_{outside} = 70 - (-20) = 90°$ F.

Note: Degree days may be used for system design instead of design temperatures:

Zone 1, 9,000 degree days
Zone 2, 8,000 degree days
Zone 3, 7,500 degree days
Zone 4, 7,000 degree days

Step 2: Using section ILHR 22.06 or 22.12, determine the insulation values for the exterior walls above grade and the roof/ceiling for Phase I.

Exposed exterior walls above grade; $U_o = .15$
Roof/ceiling; $U_o = .033$

Step 3: Fill in the worksheet to determine requirements for building enclosure heat loss.

Step 4: Select the levels of insulation to be used and determine the U values for the ceiling, wall, box sill and foundation (shown in Figure A-1). Fill in the building enclosure worksheet.

Step 5: If the total heat loss determined through the system design method is within one percent or is less than the heat loss determined through the code requirements, the code has been satisfied.

R-VALUE DETERMINATION BY COMPONENT

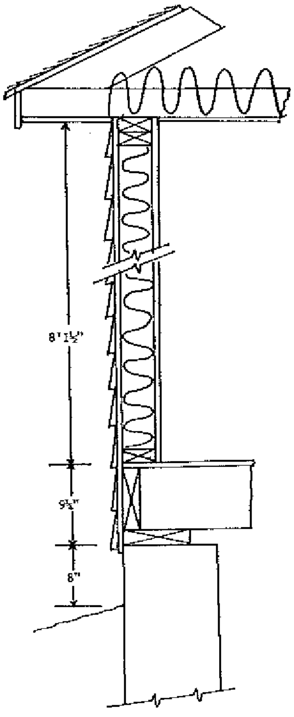


Figure A-1

Ceiling	Cavity R	Joist R
Top surface	.17	.17
Insulation	38.0	19.0
Wood	—	6.88
½" gyp. wall board	.45	.45
Bottom surface	.61	.61
	39.23	27.11
	(U=.025)	(U=.037)

Wall	Cavity R	Stud R
Outside surface	.17	.17
⅝" ext. siding	.77	.77
Rigid insulation	—	—
Insulation	11.00	—
Wood stud	—	4.38
½" gyp. wall board	.45	.45
Inside surface	.68	.68
	13.07	6.45
	(U=.070)	(U=.13)

Box sill	R
Outside surface	.17
⅝" ext. siding	.77
Rigid insulation	—
Insulation	11.00
1½" wood	1.88
Inside surface	.68
	14.50
	(U=.064)

Foundation	R
Outside surface	.17
8" concrete	.64
Inside surface	.68
Rigid insulation	5.27
	6.76
	(U=.15)

WORKSHEET FOR SYSTEM DESIGN ANALYSIS

CODE REQUIREMENTS				
Component	U_0 Reqd.	Area	ΔT	Heat Loss
Walls Above grade	.15	1512.18	90	20,414.4
Box sill	.15	150.66	70	1,581.9
Foundation	.15	124.62	70	1,308.5
Roof/Ceiling	.033	1500.00	90	4,455.0
Floor Over unheated spaces				
Slab-on-grade				
			TOTAL	27,759.9

SYSTEM DESIGN ALTERNATIVE

Component	U	Area	ΔT	Heat Loss
Walls				
Cavity	.070	1010.20	90	6,364.3
Solid	.13	252.60	90	2,955.4
Box sill	.064	150.66	70	675.0
Foundation	.15	108.97	70	1,114.2
Roof/Ceiling				
Cavity	.025	1350.00	90	3,037.5
Solid	.037	150.00	90	499.5
Floor				
Over unheated spaces				
Slab-on-grade				
Windows	.56	211.61	90	10,665.1
Doors	.31	37.82	90	1,055.2
Basement windows	1.13	15.65	70	1,237.9
			TOTAL	27,634.1

WORKSHEET FOR SYSTEM DESIGN ANALYSIS

CODE REQUIREMENTS

Component	U_0 Reqd.	Area	ΔT	Heat Loss
Walls				
Above grade				
Box sill				
Foundation				
Roof/Ceiling				
Floor				
Over unheated spaces				
Slab-on-grade				
			TOTAL	

SYSTEM DESIGN ALTERNATIVE

Component	U	Area	ΔT	Heat Loss
Walls				
Cavity				
Solid				
Box sill				
Foundation				
Roof/Ceiling				
Cavity				
Solid				
Floor				
Over unheated spaces				
Slab-on-grade				
Windows				
Doors				
Basement windows				
			TOTAL	______

TABLE A-4

COMMON CONSTRUCTION MATERIAL R-VALUES*

Material	Description		Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
BUILDING BOARD Boards, panels, subflooring, sheathing, woodbased panel products	Asbestos-cement board		120	0.25	—
	Asbestos-cement board	⅛ in.	120	—	0.03
	Asbestos-cement board	¼ in.	120	—	0.06
	Gypsum or plaster board	⅜ in.	50	—	0.32
	Gypsum or plaster board	½ in.	50	—	0.45
	Plywood		34	1.25	—
	Plywood	¼ in.	34	—	0.31
	Plywood	⅜ in.	34	—	0.47
	Plywood	½ in.	34	—	0.62
	Plywood or wood panels	¾ in.	34	—	0.93
	Insulating board				
	Sheathing, reg. density	½ in.	18	—	1.32
		25/32 in.	18	—	2.06
	Sheathing, intermediate density	½ in.	22	—	1.22
	Nail-base sheathing	½ in.	25	—	1.14
	Shingle backer	⅜ in.	18	—	0.94
	Shingle backer	5/16 in.	18	—	0.78
	Sound deadening board	½ in.	15	—	1.35
	Tile and lay-in panels, plain or acoustic		18	2.50	—
		½ in.	18	—	1.25
		¾ in.	18	—	1.89
	Laminated paperboard		30	2.00	—
	Homogeneous board from repulped paper		30	2.00	—
	Hardboard				
	Medium density siding	7/16 in.	40	—	0.67
	Other medium density		50	1.37	—
	High density, underlay		55	1.22	—
	High density std. tempered		63	1.00	—

Material	Description	Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
	Particleboard			
	Low density	37	1.85	—
	Medium density	50	1.06	—
	High density	62.5	0.85	—
	Underlayment ... ⅝ in.	40	—	0.82
	Wood subfloor ... ¾ in.	—	—	0.94
BUILDING PAPER	Vapor-permeable felt	—	—	0.06
	Vapor-seal, 2 layers of mopped 15 lb. felt	—	—	0.12
	Vapor-seal, plastic film	—	—	Negl.
ROOF INSULATION	Preformed, for use above deck			
	Approximately ... ½ in.	—	—	1.39
	Approximately ... 1 in.	—	—	2.78
	Approximately ... 1½ in	—	—	4.17
	Approximately ... 2 in.	—	—	5.56
	Approximately ... 2½ in.	—	—	6.67
	Approximately ... 3 in.	—	—	8.33
	Cellular glass	9	2.50	—
MASONRY MATERIALS	Cement mortar	116	0.20	—
Concrete	Gypsum-fiber concrete 87½% gypsum, 12½% wood chips	51	0.60	—
	Lightweight aggregates	120	0.19	—
	including expanded shale,	100	0.28	—
	clay or slate, expanded	80	0.40	—
	slags; cinders; pumice;	60	0.59	—
	vermiculite; also cellular	40	0.86	—
	concretes	30	1.11	—
		20	1.43	—
	Perlite	40	1.08	—
	...	30	1.41	—
	...	20	2.00	—
	Sand and gravel or stone aggregate (oven dried)	140	0.11	—
	Sand and gravel or stone aggregate (not dried)	140	0.08	—
	Stucco	116	0.20	—
MASONRY UNITS	Brick, common	120	0.20	—
	Brick, face	130	0.11	—
	Clay tile, hollow:			
	1 cell deep ... 3 in.	—	—	0.80
	1 cell deep ... 4 in.	—	—	1.11
	2 cells deep ... 6 in.	—	—	1.52
	2 cells deep ... 8 in.	—	—	1.85
	2 cells deep ... 10 in.	—	—	2.22
	3 cells deep ... 12 in.	—	—	2.50
	Concrete blocks, 3 oval core:			
	Sand & gravel aggregate ... 4 in.	—	—	0.71
	8 in.	—	—	1.11
	12 in.	—	—	1.28
	Cinder aggregate ... 3 in.	—	—	0.86
	... 4 in.	—	—	1.11
	... 8 in.	—	—	1.72
	... 12 in.	—	—	1.89
	Lightweight aggregate(expanded shale, clay, slate or slag; pumice) 3 in.	—	—	1.27
	4 in.	—	—	1.50
	8 in.	—	—	2.00
	12 in.	—	—	2.27
	Concrete blocks, rectangular core			
	Sand & gravel aggregate			

Material	Description	Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
	2 core, 8" 36 lb	—	—	1.04
	Same with filled cores	—	—	1.93
	Lightweight aggregate (expanded shale, clay, ... slate or slag, pumice):..................			
	3 core, 6" 19 lb ...... —	—	1.65	
	Same with filled cores .... —	—	2.99	
	2 core, 8" 24 lb ...... —	—	2.18	
	Same with filled cores .... —	—	5.03	
	3 core, 12" 38 lb..... —	—	2.48	
	Same with filled cores .... —	—	5.82	
	Stone, lime or sand................	—	0.08	—
	Gypsum partition tile:			
	3 x 12 x 30 in. solid..............	—	—	1.26
	3 x 12 x 30 in. 4-cell.............	—	—	1.35
	4 x 12 x 30 in. 3-cell.............	—	—	1.67
PLASTERING MATERIALS	Cement plaster, sand aggregate	116	0.20	—
	Sand aggregate...... ⅜ in.	—	—	0.08
	Sand aggregate...... ¾ in.	—	—	0.15
	Gypsum plaster:			
	Lightweight aggregate.............. ½ in.	45	—	0.32
	Lightweight aggregate.............. ⅝ in.	45	—	0.39
	Lightweight aggregate on metal lath .... ¾ in.	—	—	0.47
	Perlite aggregate	45	0.67	—
	Sand aggregate	105	0.18	—
	Sand aggregate...... ½ in.	105	—	0.09
	Sand aggregate...... ⅝ in.	105	—	0.11
	Sand aggregate on metal lath .... ¾ in	—	—	0.1
	Vermiculite aggregate...........	45	0.59	—
ROOFING	Asbestos-cement shingles	120	—	0.21
	Asphalt roll roofing	70	—	0.15
	Asphalt shingles.....................	70	—	0.44
	Built-up roofing....... ⅜ in	70	—	0.33
	Slate .... ½ in.	—	—	0.05
	Wood shingles, plain plastic film faced ... —	—	0.94	
SIDING MATERIALS (On flat surface)	Shingles:			
	Asbestos-cement..................	120	—	0.21
	Wood, 16", 7½" exposure......	—	—	0.87
	Wood, double, 16", 12" exposure...............................	—	—	1.19
	Wood, plus insulating backer board .... 5/16 in.	—	—	1.40
	Siding:			
	Asbestos-cement, ¼" lapped	—	—	0.21
	Asphalt roll siding................	—	—	0.15
	Asphalt insulating siding (½" bd.)	—	—	1.46
	Wood drop 1 x 8"	—	—	0.79
	Wood bevel, ½" x 8" lapped	—	—	0.81

Material	Description	Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
	Wood bevel, ¾ x 10" lapped	—	—	1.05
	Wood plywood ⅜" lapped	—	—	0.59
	Aluminum or steel, over sheathing, hollow-backed	—	—	0.61
	Insulating-board backed nominal ⅜"	—	—	1.82
	Insulating-board backed nominal ⅜" foil backed	—	—	2.96
	Architectural glass	—	—	0.10
FINISH FLOORING MATERIALS	Carpet and fibrous pad	—	—	2.08
	Carpet and rubber pad	—	—	1.23
	Cork tile ⅛ in.	—	—	0.28
	Terrazzo 1 in.	—	—	0.08
	Tile-asphalt, linoleum, vinyl, rubber	—	—	0.05
	Wood, hardwood finish ¾ in.	—	—	0.08
INSULATING MATERIALS Blanket and batt	Mineral fiber, fibrous form processed from rock, slag or glass			
	Approx. 2 to 2¾" ... Note 1	—	—	7
	Approx. 3 to 3½" ... Note 1	—	—	11
	Approx. 5¼ to 6½" Note 1	—	—	19
Board and Slabs	Cellular glass	9	2.50	—
	Glass fiber, organic bonded	4-9	4.00	—
	Expanded rubber (rigid)	4.5	4.55	—
	Expanded polystyrene extruded, plain	1.8	4.00	—
	Expanded polystyrene extruded (R-12 exp.)	2.2	5.00	—
	Expanded polystyrene extruded (R-12 exp.) (Thickness 1" and greater)	3.5	5.26	—
	Expanded polystyrene, molded beads	1.0	3.57	—
	Expanded polyurethane (R-11 exp.)	1.5	6.25	—
	Mineral fiber with resin binder.	15	3.45	—
	Mineral fiberboard wet felted			
	Core or roof insulation	16-17	2.94	—
	Acoustical tile	18	2.86	—
	Acoustical tile	21	2.70	—
	Mineral fiberboard wet molded			
	Acoustical tile	23	2.38	—
	Wood or cane fiberboard			
	Acoustical tile ½ in.	—	—	1.25
	Acoustical tile ¾ in.	—	—	1.89
	Interior finish (plank, tile)	15	2.86	—
	Insulating roof deck			
	Approximately 1½ in.	—	—	4.17
	Approximately 2 in.	—	—	5.56
	Approximately 3 in.	—	—	8.33
	Wood shredded (cemented in preformed slabs)	22	1.67	—
	Foil faced, glass fiber — reinforced cellular polyisocyanurate	2	7.04	—
	Nominal 0.5 in.	2	—	3.6
	Nominal 1.0 in.	2	—	7.2
	Nominal 2.0 in.	2	—	14.4

Material	Description	Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
Loose Fill	Cellulose insulation (milled paper or wood pulp)	2.5-3	3.70	—
	Sawdust or shavings	0.8-1.5	2.22	—
	Wood fiber, softwoods	2.0-3.5	3.33	—
	Perlite, expanded	5.0-8.0	2.70	—
	Mineral fiber (rock, slag or glass):			
	Approximately 3" .... Note 1	8-15	—	9
	Approximately 4½" .... Note 1	8-15	—	13
	Approximately 6¼" .... Note 1	8-15	—	19
	Approximately 7¼" .... Note 1	8-15	—	24
	Silica aerogel..........	7.6	5.88	—
	Vermiculite (expanded)..........	7.0-8.2	2.13	—
	....	4.0-6.0	2.27	—
WOODS	Maples, oak and similar hardwoods..........	45	0.91	—
	Fir, pine, and similar softwoods..........	32	1.25	—
	Fir, pine, and similar softwoods .... ¾ in.	32	—	0.94
	.... 1½ in.	32	—	1.89
	.... 2½ in.	32	—	3.12
	.... 3½ in.	32	—	4.35

Note 1: R-value varies with fiber diameter. Insulation is produced by different densities; therefore, there is a wide variation in thickness for the same R-value between various manufacturers. (See Batt and Loose Fill Insulation.)

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TABLE A-5

COEFFICIENTS OF TRANSMISSION (U) OF WINDOWS, SKYLIGHTS, AND LIGHT TRANSMITTING PARTITIONS*

(These values are for heat transfer from air to air.)
Btu per (hr) (sq ft) (F Deg)

PART A
VERTICAL PANELS (EXTERIOR WINDOWS, SLIDING PATIO DOORS AND PARTITIONS) — FLAT GLASS, GLASS BLOCK AND PLASTIC SHEET

Description	Exterior[1]		
	Winter	Summer	Interior
Flat Glass			
single glass	1.13	1.06	0.73
insulating glass—double[2]			
3/16 in. air space	0.69	0.64	0.51
¼ in. air space	0.65	0.61	0.49
½ in. air space	0.58	0.56	0.46
½ in. air space, low emissivity coating[3]			
emissivity = 0.20	0.38	0.36	0.32
emissivity = 0.40	0.45	0.44	0.38
emissivity = 0.60	0.52	0.50	0.42
insulating glass—triple[2]			
¼ in. air spaces	0.47	0.45	0.38
½ in. air spaces	0.36	0.35	0.30
storm windows			
1 in.-4 in. air space	0.56	0.54	0.44
Glass Block[4]			
6 x 6 x 4 in. thick	0.60	0.57	0.46
8 x 8 x 4 in. thick	0.56	0.54	0.44
—with cavity divider	0.48	0.46	0.38
12 x 12 x 4 in. thick	0.52	0.50	0.41
—with cavity divider	0.44	0.42	0.36
12 x 12 x 2 in. thick	0.60	0.57	0.46
Single Plastic Sheet	1.09	1.00	0.70

[1]See Part C for adjustment for various window and sliding patio door types.
[2]Double and triple refer to the number of lights of glass.
[3]Coating on either glass surface facing air space; all other glass surfaces uncoated.
[4]Dimensions are nominal.

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PART B
HORIZONTAL PANELS (SKYLIGHTS) FLAT GLASS, GLASS BLOCK AND PLASTIC BUBBLES

Description	Exterior[1]		
	Winter[5]	Summer[6]	Interior[5]
Flat Glass			
single glass	1.22	0.83	0.96
insulating glass—double[2]			
3/16 in. air space	0.75	0.49	0.62
¼ in. air space	0.70	0.46	0.59
½ in. air space	0.66	0.44	0.56
½ in. air space, low emissivity coating[3]			
emissivity = 0.20	0.46	0.31	0.39
emissivity = 0.40	0.53	0.36	0.45
emissivity = 0.60	0.60	0.40	0.50
Glass Block[4]			
11 x 11 x 3 in. thick with cavity divider	0.53	0.35	0.44
12 x 12 x 4 in. thick with cavity divider	0.51	0.34	0.42
Plastic Bubbles[7]			
single walled	1.15	0.80	—
double walled	0.70	0.46	—

[5]For heat flow up.
[6]For heat flow down.
[7]Based on area of opening, not total surface area.

(See following page for Part C of this table.)

PART C
ADJUSTMENT FACTORS FOR VARIOUS WINDOW AND SLIDING PATIO DOOR TYPES
(Multiply U values in Parts A and B by these factors)

Description	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All Glass[8]	1.00	1.00	1.00
Wood Sash—80% Glass	0.90	0.95	0.90
Wood Sash—60% Glass	0.80	0.85	0.80
Metal Sash—80% Glass	1.00	1.20	1.20[9]
Sliding Patio Doors			
Wood Frame	0.95	1.00	—
Metal Frame	1.00	1.10	—

[8]Refers to windows with negligible opaque area.
[9]Value becomes 1.00 when storm sash is separated from prime window by a thermal break.

TABLE A-6

COEFFICIENTS OF TRANSMISSION (U) FOR SLAB DOORS*
Btu per (hr) (sq ft) (F Deg)

Thickness[1]	Winter			Summer, No Storm Door
	Solid Wood, No Storm Door	With Storm Door: Wood	With Storm Door: Metal	
1 in.	0.64	0.30	0.39	0.61
1¼ in.	0.55	0.28	0.34	0.53
1½ in.	0.49	0.27	0.33	0.47
2 in.	0.43	0.24	0.29	0.42
	Steel Door			
1¾ in.				
A[3]	0.59	—	—	0.58
B[4]	0.19	—	—	0.18
C[5]	0.47	—	—	0.46

[1]Nominal thickness.

[2]Values for wood storm doors are for approximately 50% glass; for metal storm doors values apply for any percent of glass.

[3]A = Mineral fiber core (2 lb/cu ft).

[4]B = Solid urethane foam core with thermal break.

[5]C = Solid polystyrene core with thermal break.

Note: Hollow core doors 1⅜ in. thick - R = 2.17; U = 0.46
1¾ in. thick - R = 2.22; U = 0.45

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APPENDIX B

FORMULA FOR DETERMINING THE OVERALL U_o OF THE WALL

$$U_o = \frac{U_{cav}A_{cav} + U_{sol}A_{sol} + U_{win}A_{win} + U_{door}A_{door} + U_{box}A_{box} + U_{found}A_{found}}{A_o}$$

Where:

U_o	=	Overall thermal transmittance of gross wall area
A_o	=	Gross area of exterior walls
U_{cav}	=	Thermal transmittance of cavity area (usually assume 80%)
A_{cav}	=	Area between wall framing where insulation may be placed
U_{sol}	=	Thermal transmittance of wood framing area
A_{sol}	=	Area of wood framing (usually assume 20%)
U_{box}	=	Thermal transmittance of box sill area
A_{box}	=	Area of box sill
U_{found}	=	Thermal transmittance of foundation area
A_{found}	=	Area of above grade exposed concrete
U_{win}	=	Thermal transmittance of window
A_{win}	=	Total glass area
U_{door}	=	Thermal transmittance of door
A_{door}	=	Total door area

FORMULA FOR DETERMINING THE OVERALL U_o OF THE CEILING

$$U_o = \frac{U_{cav}A_{cav} + U_{sol}A_{sol} + U_{skylight}A_{skylight}}{A_o}$$

Where:

U_o	=	Overall thermal transmittance of gross roof/ceiling
A_o	=	Gross area of roof/ceiling assembly
U_{cav}	=	Thermal transmittance of cavity area
A_{cav}	=	Area between wood framing
U_{sol}	=	Thermal transmittance of framing
A_{sol}	=	Area of wood framing (usually assume 10%)
$U_{skylight}$	=	Thermal transmittance of skylight elements
$A_{skylight}$	=	Area of skylight (including frame)

APPENDIX C

INSULATION, EQUIPMENT AND CONDENSATION CONTROL

This appendix is a guide for the proper installation of insulation. The preceding appendices indicated the required amounts and types of insulation necessary to provide the various thermal resistance values for the building envelope. In order to attain the resistance values specified, it is important that the insulation be properly installed. This appendix includes types of materials currently available and common application practices.

Condensation control should be provided in the form of vapor barriers and thermal breaks. Vapor barriers should be installed on the warm side (area heated in winter) of all walls, ceilings, and insulated floors. All metal window, skylight, and door frames should contain a thermal break.

Insulation is manufactured in many forms and types. The most commonly used materials in residential construction are batts and blankets, rigid insulation, reflective insulation, loose fill, and sprayed insulation. The following is a list of types of materials and the federal specifications governing their characteristics.

Cork board	FS HH-I-561
Cellular glass	FS HH-I-551
Duct insulation	FS HH-I-558b
Expanded polystyrene insulation board	FS HH-I-524
Fiberboard	FS LLL-I-535 or ASTM C-208 Class C
Insulation board (urethane)*	FS HH-I-530
Insulation, thermal (perlite)	FS HH-I-574
Mineral fiber, pneumatic or poured	FS HH-I-1030A
Mineral fiber, insulation blanket	FS HH-I-521E
Perlite	FS HH-I-526a
Perimeter insulation	FS HH-I-524a Type II
	FS HH-I-558b Form A, Class 1 or 2
Reflective, thermal	FS HH-I-1552
Structural fiberboard insulation roof deck	AIMA IB Spec. No. 1
Cellulose; vegetable or wood fiber	FS HH-I-515b-25
Vermiculite	FS HH-I-585
Vermiculite, water repellent loose fill	FHA UM-30
Mineral fiber, roof insulation	HH-I-526c

BATTS AND BLANKETS

These materials are usually identified on the package and on the vapor barrier facing with their "R" values. Under the federal specifications, there are 3 standard products identified as R-7, R-11, and R-19. These values are based on the insulation value of the mass. Some manufacturers offer other products such as R-8, R-13 and R-22. The specific thickness of insulation required for a specific "R" value may vary from one manufacturer to another due to differences in base materials and manufacturing processes.

General Guidelines

1. Install insulation so the vapor barrier faces the interior of the dwelling.
2. Vapor barriers should not be left exposed.
3. Insulate all voids of the building envelope including small spaces, gaps, around receptacles, pipes, etc.
4. Place insulation on the cold side of pipes and ducts (see Fig. 4). Insulation is not required for supply and return air ducts in heated basements and cellars.

Ceilings

There is a variety of methods for installing blanket insulation in ceilings.

1. Fastening from below (Fig. 1b).
2. Installing unfaced (without a vapor barrier), friction-fit blankets (Fig. 2).
3. Laying the insulation in from above when the ceiling finish material is in place (Fig. 1a).

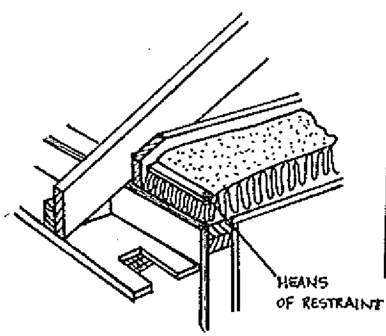


Fig. 1a

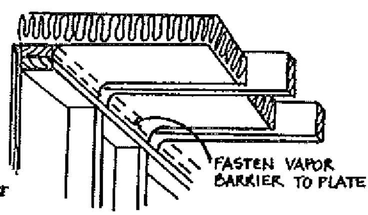


Fig. 1b

Fasten flanges to the inside of ceiling joists as shown in Fig. 1b. Extend the insulation entirely across the top plate, keeping the blanket as close to the plate as possible. Fasten vapor barrier to plate. When eave vents are used, the insulation should not block air movement from eave to space above insulation (Fig. 1a).

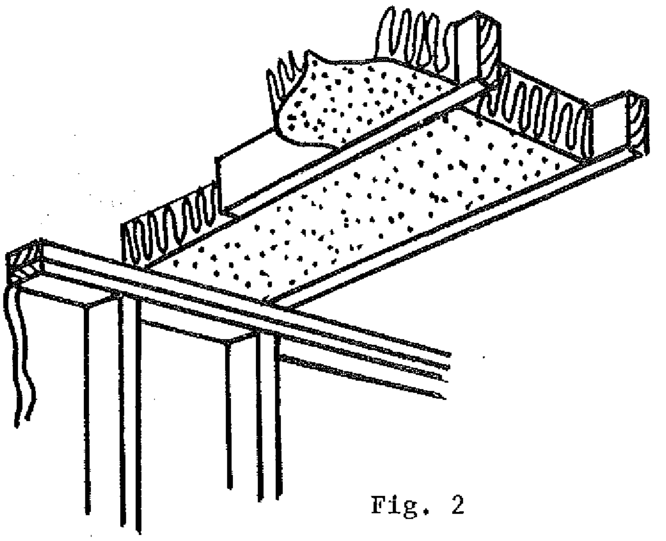


Fig. 2

Insert friction-fit blankets between ceiling joists (Fig. 2). Allow insulation to overlap the top plate of the exterior wall, but not enough to block eave ventilation. The insulation should be in contact with the top of the plate to avoid heat loss and air infiltration beneath the insulation. The required vapor barrier is not shown.

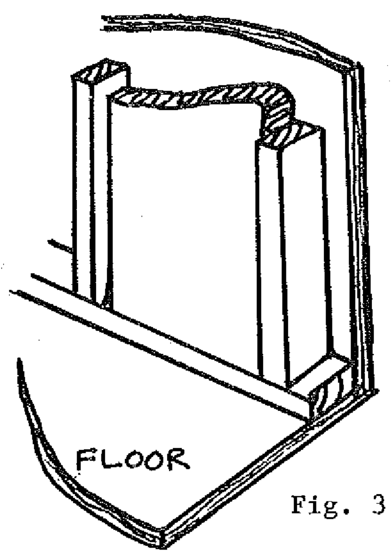


Fig. 3

Insert blankets into stud spaces. Working from the top down, space fasteners per manufacturers recommendations, fitting flanges tightly against face of stud (Fig. 3). Cut blankets slightly over length and fasten the vapor barrier to the top and bottom plates.

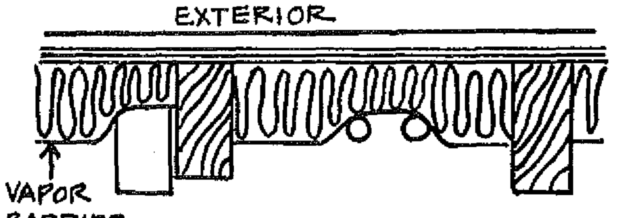


Fig. 4

Insert insulation behind (cold side in winter) pipes, ducts, and electrical boxes (Fig. 4).

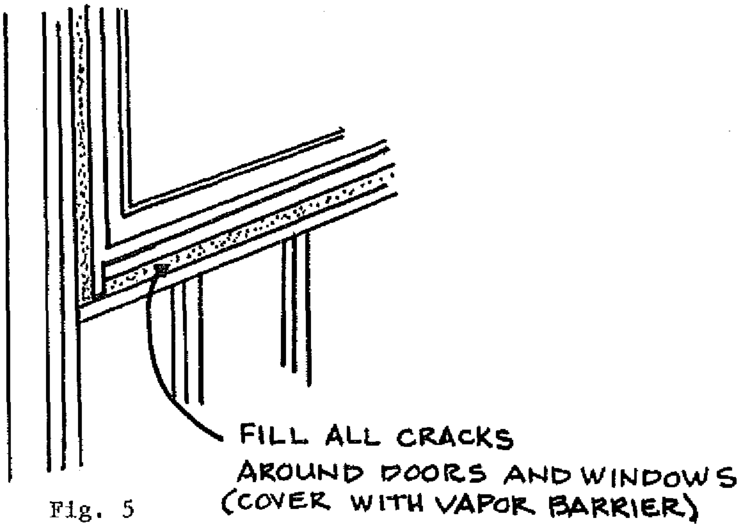


Fig. 5

Fill small spaces between rough framing and door and window heads, jambs and sills with pieces of insulation (Fig. 5).

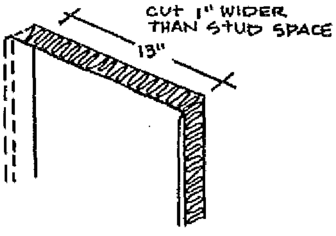


Fig. 6a

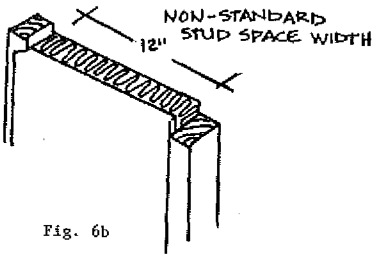


Fig. 6b

Insulate nonstandard-width stud or joist spaces by cutting the insulation and vapor barrier an inch or so wider than the space to be filled (Fig. 6a). Pull the vapor barrier on the cut side to the other stud, compressing the insulation behind it, and fasten through vapor barrier to stud face (Fig. 6b). Unfaced blankets are cut slightly oversize and fitted into place.

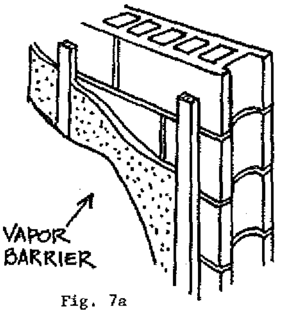


Fig. 7a

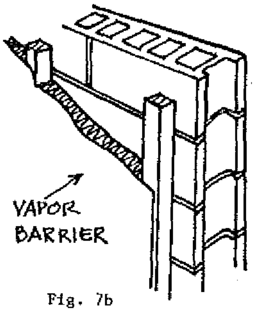


Fig. 7b

Masonry walls may be insulated by inserting insulation between furring strips spaced at 16 or 24 inches o.c. (Fig. 7a and 7b). It is recommended to apply the vapor barrier to the inside surface.

Floor and Crawl Spaces

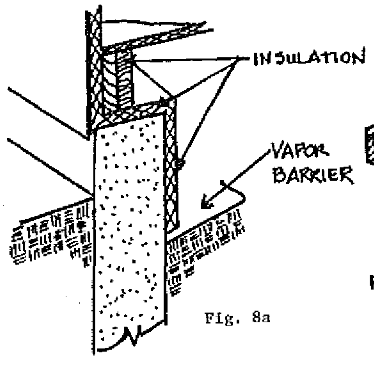


Fig. 8a

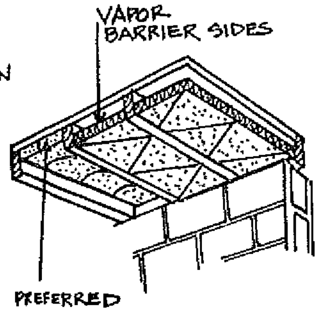


Fig. 8b

Floors over crawl spaces (Fig. 8a) should be insulated either by insulating the foundation walls or by placing insulation on or between the joists. Insulation should be securely fastened. In all cases, the vapor barrier side of the insulation should face the floor above; that is, be adjacent to the warm side in winter. A vapor barrier should be used to cover the ground.

Dropped Soffits

Insulation of dropped soffits over kitchen cabinets, bathtubs, showers, or similar areas, need special attention when they are exposed to the attic. If the dropped soffit is framed before ceiling finish material is applied, a "board" (plywood, hardboard, gypsumboard, etc.) should be installed over the cavity to support insulation.

In multiple dwellings with back-to-back kitchens or baths, it is necessary to extend ceiling finish material over dropped soffits to the party wall to avoid loss of acoustical control and to provide adequate fire stops.

Rigid Insulation

Rigid insulation is available in various sizes and thicknesses made of polystyrene, polyurethane, cork, cellular glass, mineral fiber (glass or rock wool), perlite, wood fiberboard, etc. They are used as insulation for masonry construction, as perimeter insulations around concrete slabs, as exterior sheathing under the weather barrier, as rigid insulations on top of roof decks, and other applications. Rigid insulations, such as polystyrene and polyurethane, are vapor barriers and, in most applications, will not require the installation of a separate barrier.

Installation Procedures

Masonry walls: Rigid insulations are applied to either face of a masonry wall(Fig. 9a and 9c) or are used as a cavity insulation between two wythes of masonry (Fig. 9b). When applied to the face of masonry walls, they are generally installed with adhesive and/or mechanical fasteners. The manufacturer's recommendation should be followed.

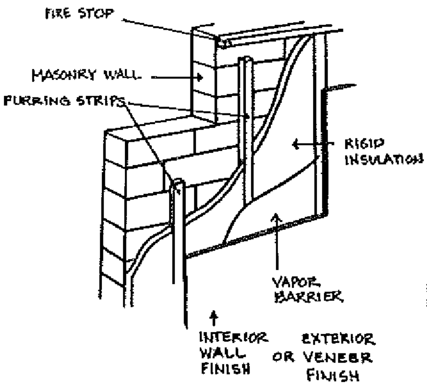


Fig. 9a

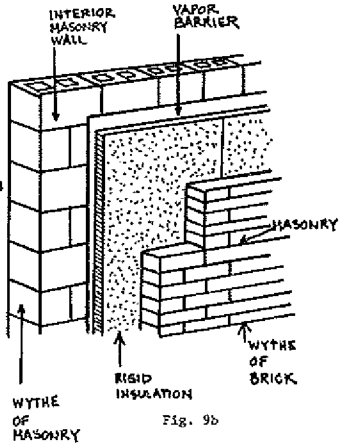


Fig. 9b

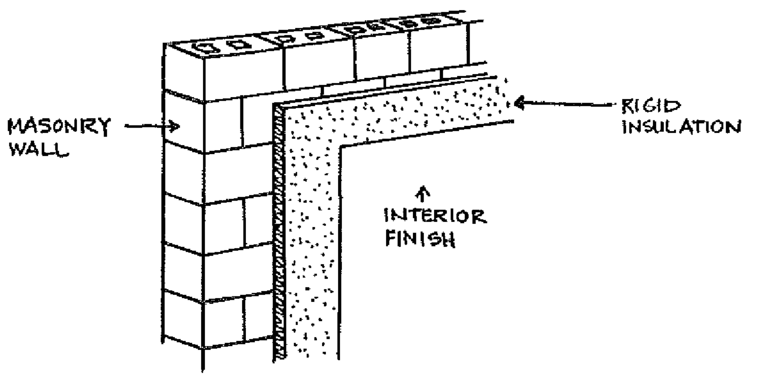


Fig. 9c

Frame Construction: When rigid insulation is used with frame construction (Fig. 10), it is usually applied as sheathing to the outside of the framing, and mechanically attached with nails to wood studs or to metal studs with screws or clips or other approved methods.

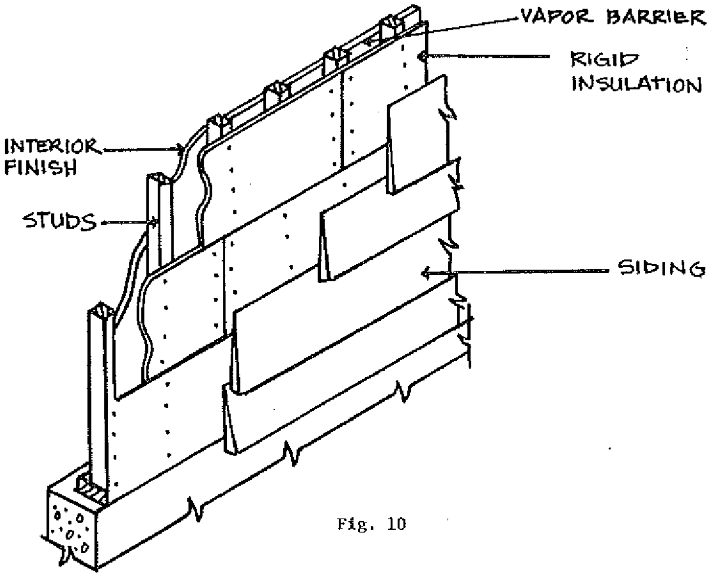


Fig. 10

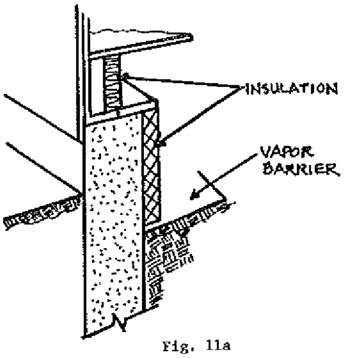


Fig. 11a

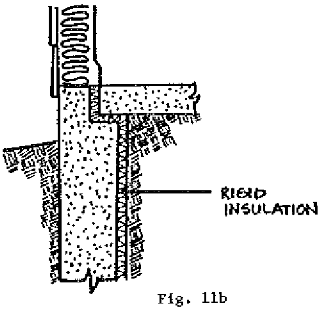


Fig. 11b

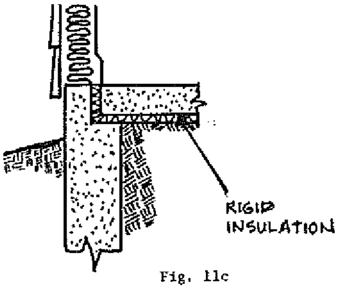


Fig. 11c

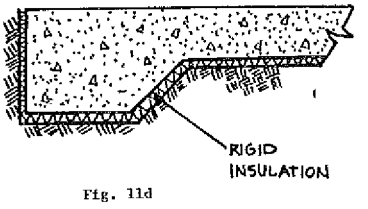


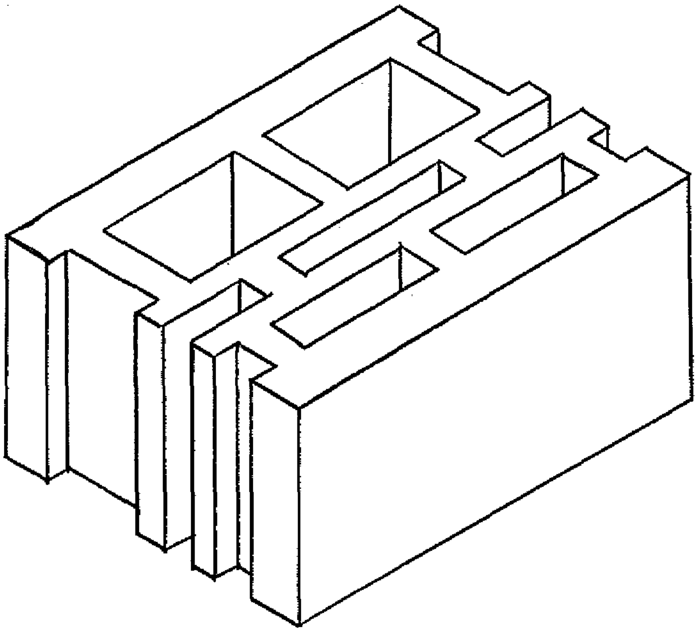
Fig. 11d

Roof Insulation: Roof insulation boards are usually installed with an approved adhesive, hot asphalt, or may be nailed to the roof sheathing. The manufacturer's instructions should be followed.

Slab-on-Grade: Rigid insulation is frequently used as insulation around the perimeter of concrete slabs-on-grade (Fig. 11b, c, d) and also may be used on the inside of foundation walls adjacent to heated crawl spaces, basements or cellars (Fig. 11a). Installation is usually accomplished with adhesive and/or mechanical fasteners. Perimeter insulation should be installed against the foundation wall or extended into the interior of the building to a distance equal to the design frost line (Fig. 11b, c and d). Where the slab bears on the foundation ledge, the insulation should be a load-bearing type.

INSULATED CONCRETE BLOCK

Concrete block manufacturers are currently producing several types of multi-celled block with improved insulating values. The thermal resistance of the block will vary depending upon the types of insulation used and the configuration of the cells. An example of a typical multi-celled block is shown below.



LOOSE FILL INSULATION

Materials of this type are those made from mineral fibers (rock or glass), cellulose materials (wood fibers or shredded paper), or other manufactured products that can easily be poured.

BLOWN ATTIC INSULATION

There are several factors pertaining to blown attic insulation that can cause differences in its installed thermal resistance value (R). For a given manufacturer's insulation, the installed thermal resistance (R) value depends on thickness and weight of insulating material applied per square foot. Federal specification HH-I-1030A for insulation requires that each bag of insulation be labeled to show the minimum thickness, the maximum net coverage, and the minimum weight of (that particular) insulation material required per square foot to produce resistance values of R-30, 22, 19, and 11. A bag label example for blown insulation is shown in Fig. 12.

The number of bags of blown insulation required to provide a given R-value to insulate an attic of a given size may be calculated from data provided by the manufacturer. If only the thickness of blown attic insulation is specified, and the density or number of bags is not, the desired or assumed thermal resistance (R) value may not be achieved. The important characteristic is weight per square foot. Thickness is the minimum thickness, not the average thickness experienced in the field.

Adequate baffling of the vent opening or insulation blocking should be provided so as to deflect the incoming air above the surface of the installed blown or poured insulation. Baffles should be made of durable material securely fastened. Baffles should be in place at the time of framing inspection.

Three blown insulations that provide R-19 are:

Material	Minimum Thickness	Maximum Net Coverage/Bag	Bags/1000 Sq. Ft.
Cellulose	5⅝"	59 sq. ft. (40 lb. bag)	17
Glass fiber	8¾"	51 sq. ft. (24 lb. bag)	20
Rock wool	6½"	26 sq. ft. (27 lb. bag)	38

Bag Label Example: The manufacturer recommends these maximum coverages at these minimum thicknesses to provide the levels of installed insulation resistance (R) values shown:

(Based on 25-pound nominal weight bag)

R-Value	Minimum Thickness	Minimum Weight per Sq. Ft.	Bags per 1000 Sq. Ft.	Maximum Net Coverage per Bag
To obtain an insulation resistance R of:	Installed insulation should not be less than:	The weight per sq. ft. of installed insulation should be not less than:	Number of bags per 1000 sq. ft. of net area should not be less than:	Contents of this bag should not cover more than:
R-30	13¾ in. thick	0.768 lbs. per sq. ft.	30	33 sq. ft.
R-22	10 in. thick	0.558 lbs. per sq. ft.	22	45 sq. ft.
R-19	8¾ in. thick	0.489 lbs. per sq. ft.	20	51 sq. ft.
R-11	5 in. thick	0.279 lbs. per sq. ft.	11	90 sq. ft.

Weight contents: not less than 24 lbs.

R-values are determined in accordance with ASTM C-687 and C-236

Fig. 12

REFLECTIVE INSULATION

Reflective insulation is composed of aluminum foil in one or more layers either plain or laminated to one or both sides of kraft paper for structural strength. The insulation value for reflective air spaces, which this type of insulation provides, varies widely depending on the direction of heat flow. They are much more efficient when the heat flow is *down*. Reflective insulations which comply with the requirements when used in a floor, may not be satisfactory in ceilings or walls, where the heat flow is upward and horizontal, respectively. Reflective insulations are effective in controlling radiant heat energy when installed so that they face an air space. Insulation should be installed in such a manner that it is continuous, without holes or tears.

SPRAYED INSULATION

There are several types of insulation which are sprayed against the surface of the building materials or in cavities. Some of these are cellulose with binder, mineral wool with binder, and cellular foams. They may be sprayed directly on concrete, masonry, wood, plastic, or metal panels or may be sprayed between the framing members. Manufacturer's recommended instructions should be followed. To determine that the proper thickness is installed, either refer to the plans and specifications, or request a certification from the supplier that the insulation installed provides the required "R" value.

TYPICAL INSULATION THICKNESSES AND VALUES

Insulation	Approximate R-Value	Thickness
Fiber glass	11	3½″
Fiber glass	13	3⅝″
Fiber glass	19	6″
Fiber glass	30	8″
Fiber glass	38	12″
Extruded Polystyrene Foam	5.4	1″
Extruded Polystyrene Foam	10.8	2″

VAPOR BARRIERS

Vapor barriers are used in conjunction with insulation to decrease the chance of moisture condensation inside the building insulation. Vapor barriers are placed on the side of the wall, ceiling or floor that is warm in winter. For equal vapor pressures, moisture vapor penetration through holes or tears in the insulation vapor barrier is proportional to the size of the opening. Holes or tears should be repaired. A snug fit of blanket flanges against the framing is necessary to prevent moisture from bypassing the vapor barrier.

EQUIPMENT

The installation of the heating system can contribute to inefficiencies. A furnace which is oversized by a factor of 2 will require 8 to 10% more fuel than a furnace of correct size. An installation that has uninsulated ducts passing through an unheated crawl or attic space will lose about 1.5 Btu per hour per square foot of duct per degree of temperature differential between duct air and outside air. This can amount to 40% of a furnace output under mild conditions. Undersized ducting will reduce the amount of circulating air and will affect the capacity of the furnace, but will normally have little effect upon its efficiency. Atmospheric combustion equipment that draws its combustion and stack-dilution air from the heated space will require up to 8% more fuel in a season to heat the required makeup air than sealed combustion equipment. Stack heat recovery devices can recover from about 4% at 450° F to 8% at 800° F.

The appliance manufacturer should be consulted when retrofitting the appliance with combustion air to assure that the appliance warranty is not affected.

Effect of Sizing Limitation on Equipment

Using the example on system design illustrated in Appendix A, an analysis was made to see what impact or problem the proposal for limiting the size of equipment to 15% above the design losses would have.

Example:

Total construction loss	27,760 Btu/hour
One air change per hour:	
Inside volume = 12,188 cu. ft. Q = (12,188) (90) (.018) = 19,744 Btu/hour	
Total infiltration loss	19,744 Btu/hour
	47,504 Btu/hour

Maximum furnace size:

47,504 Btu/hour + 47,504 (.15) Btu/hour = 54,630 Btu/hour

COMBUSTION AIR FOR FIREPLACES

It is recommended that combustion air from the exterior be provided for all fireplaces. Masonry fireplaces can be made more energy efficient with combustion air terminating in the fireplace. The opening of the fireplace should be equipped with a door and the combustion air duct with a damper and a louver to minimize air leakage during periods of nonuse.

CONDENSATION CONTROL

Air Infiltration

The department will accept infiltration losses determined by the air crack method or an overall value of ½ air change per hour.

The department will accept the use of engineered top-side moisture vent systems.

Relative Humidity

Winter: During the winter it is desirable to have humidity in the air in order to prevent the nostrils from becoming dry, furniture from cracking, etc. However, from an energy standpoint, it is desirable to keep the relative humidity low; the trade-off is at about 30%.

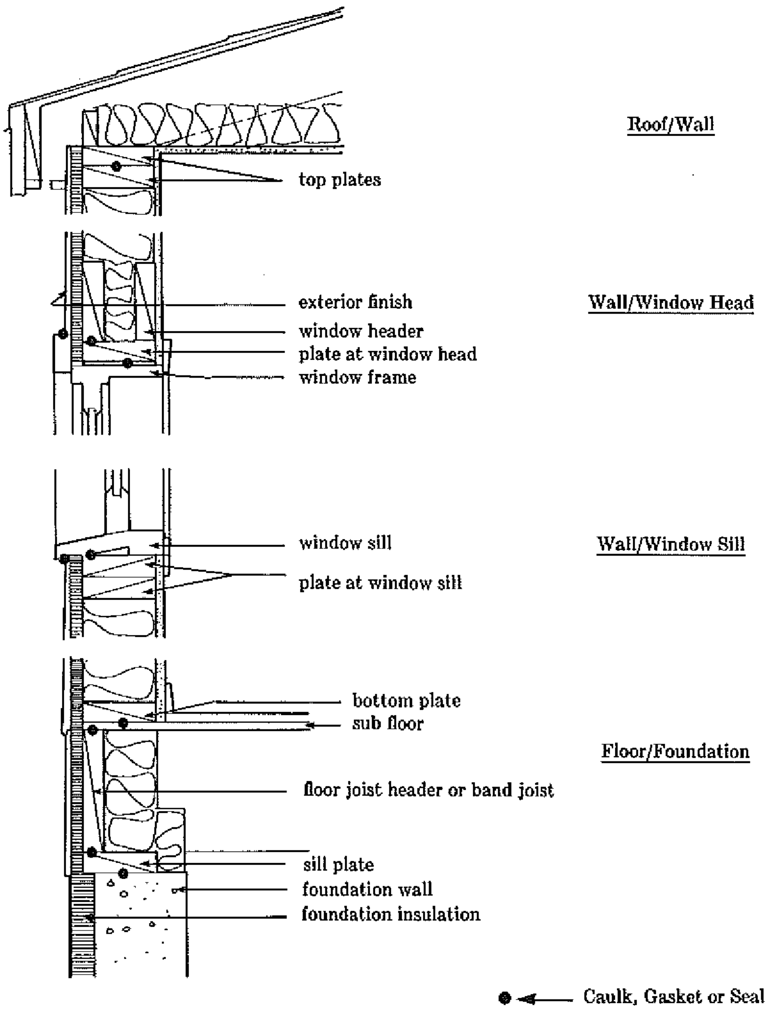
Summer: During the summer it is desirable to reduce the level of relative humidity in the building in relationship to the outside relative humidity. The relative humidity should be kept as high as possible in order to conserve energy, but low enough for comfort. The relative humidity should be kept above 55%, but less than 60%.

APPENDIX D

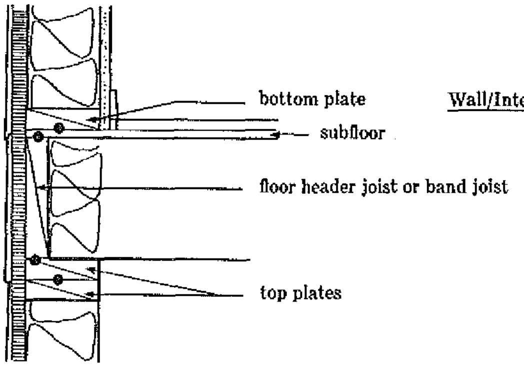
ILLUSTRATIONS OF EXTERIOR OPENINGS IN THE THERMAL ENVELOPE

The following illustrations show some exterior openings in the thermal envelope which may be sealed to control infiltration. A detailed list of sealing requirements for electrically heated homes is given in s. ILHR 22.13 (3).

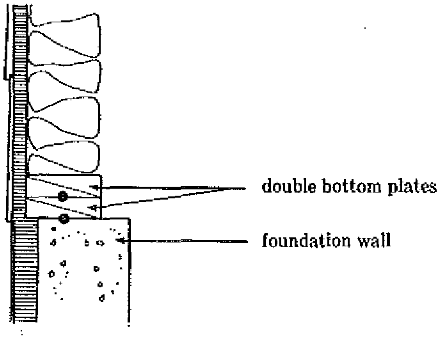
ILHR 22.13 Infiltration Control for Electrically Heated Homes



ILHR 22.13 Infiltration Control for Electrically Heated Homes (continued)



Wall/Intermediate Floor



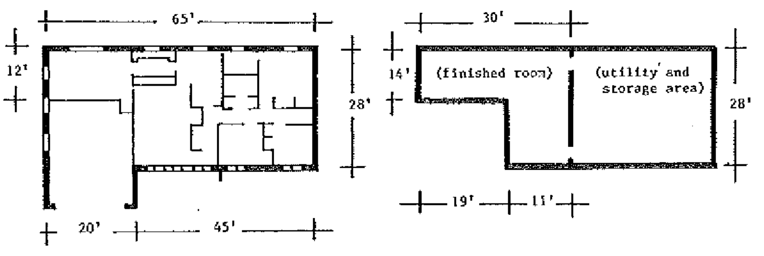
Wall/Foundation

APPENDIX E

CALCULATION OF VENTILATION REQUIREMENTS

The following examples show one way to calculate the cubic feet per minute (CFM) ventilation capacity necessary to meet the requirements of s. ILHR 22.11 (4) for electrically heated homes, and how to calculate the number of air changes delivered by a system.

Example problem #1: Calculate the minimum necessary CFM ventilating capacity for the sample dwelling. The thermal envelope of the sample dwelling encloses the following areas, excluding the garage:



FIRST FLOOR BASEMENT LEVEL

Step #1: Calculate the volume of air contained in the living space

FIRST STORY

The first story interior has 1556 square feet of floor area and 8 foot ceilings. The first floor volume is the floor area multiplied by the ceiling height:

Volume = 1556 sq. ft. × 8 ft. = 12,448 cu. ft.

Next, calculate the volumes (= length × width × height) of spaces which are not living spaces.

Closets		1050 cu. ft.
Utility Room		308 cu. ft.
Vanity in Bath		14 cu. ft.
Storage cabinets		58 cu. ft.
Book shelves		22 cu. ft.
Kitchen cabinets		176 cu. ft.
China cabinets		24 cu. ft.
Fire place		112 cu. ft.
Interior walls		399 cu. ft.
	TOTAL	2163 cu. ft.

Subtracting these volumes from the first floor volume gives the volume to be ventilated.

12,448 cu. ft. − 2163 cu. ft. = 10,285 cu. ft.

BASEMENT

The basement has one habitable room which must be ventilated. The room is 575 square feet, the ceiling height is 8 feet.

Volume = 575 sq. ft. × 8 ft. = 4600 cu. ft.

The total living space volume is the sum of the volumes on each story.

Total volume = 10,285 cu. ft. + 4600 cu. ft. = 14,885 cu. ft.

This is the volume of the air which must be exhausted to provide one air change to the living space.

Step #2: Calculate the required CFM capacity.

Use the following formula:

$$CFM = \frac{V \times ach}{60}$$

Where:

CFM = the required exhaust capacity in cubic feet per minute.

V = the volume of air in the space to be ventilated, in cubic feet.

ach = the desired number of air changes per hour. Section ILHR 22.11 (4) requires a minimum of 0.5 air changes per hour for electrically heated homes.

In this case:

$$CFM = \frac{14{,}885 \text{ cu. ft.} \times 0.5 \text{ ach}}{60} = 124 \text{ CFM}$$

A fan or fans with a total effective exhaust capacity of 124 CFM or more would provide 0.5 air changes per hour. The effective capacity is the amount of ventilation actually delivered by the installed system, taking into account any resistance to air flow due to duct work.

Example problem #2: Calculate the number of air changes per hour (ach) which are delivered by an installed ventilation system. If two bathroom fans, each with an effective exhaust rate of 50 cfm, and a kitchen fan with an effective exhaust rate of 200 cfm are installed in the sample dwelling, how may air changes per hour is the system capable of providing?

Step #1: Calculate the volume of the living space as in step #1 of Example #1. The volume of the living space is 14,885 cubic feet.

Step #2: Calculate the capacity in air changes per hour with the following formula:

$$\text{ach} = \frac{\text{CFM} \times 60}{\text{V}}$$

Where:

ach = the number of air changes per hour that the system is capable of providing.

CFM = the total effective exhaust capacity of the system, in cubic feet per minute.

V = the volume of the space which is ventilated, in cubic feet.

In this case, CFM equals the total effective capacity of the three fans in the kitchen and baths:

$$\text{CFM} = 200 + 50 + 50 = 300 \text{ CFM}$$

$$\text{ach} = \frac{300 \times 60}{14{,}885} = 1.2 \text{ air changes per hour.}$$

The ventilation system is capable of providing 1.2 air changes per hour to the living space.