ILHR 21.27 (3)(a)1. REFERENCE MATERIAL -- ROOFING SHINGLES

The *Residential Asphalt Roofing Manual* can be purchased from the Asphalt Roofing Manufacturers Association at 6000 Executive Boulevard, Suite 201, Rockville, Maryland 20852-3803. This manual contains extensive information about how shingles are manufactured; the importance of adequate roof ventilation; slope limitations; selecting, estimating, and applying roofing materials and accessories; and inspecting and maintaining the finished roof. It includes a recommendation that properly driven and applied nails be utilized as the preferred fastening system for asphalt shingles.

Results of independent testing of various shingles may be indicated on shingle packages, or may be available from either the shingle manufacturer, or the Midwest Roofing Contractors Association at 4840 West 15th Street, Suite 1000, Lawrence, Kansas 66049-3876.

APPENDIX A

CHAPTER ILHR 22
DETERMINATION OF REQUIRED LEVELS OF INSULATION USING THE ENERGY WORKSHEET

Two methods may be used to determine the level of insulation required by Chapter ILHR 22 for electrically heated and non- electrically heated dwellings. The Component Method (also known as the Accepted Practice Method) can be used with a minimum of calculations and is recommended for standard designs. The System Design Method is more complex and is used for alternate designs. Under the System Design Method, less insulation may be installed in one building component if more insulation is installed in another.

The following illustration demonstrates use of the Energy Worksheet to determine the required levels of insulation. Single copies of the Energy Worksheet are available at no charge upon written request.

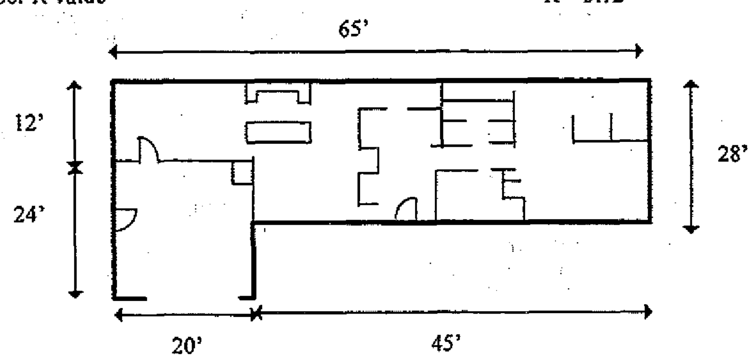
Write to:
Department of Industry, Labor and Human Relations
Division of Safety and Buildings
Post Office Box 7969
Madison, Wisconsin 53707

Portions A and H of the Energy Worksheet must be filled out for the Component Method. Portions B, C and D of the Energy Worksheet must be filled out to use the System Design Method. Sections B and F are filled out to size the furnace for either method. Section G must be filled out to size the ventilation system for electrically heated homes. Both the Component Method and the System Method will be shown in the illustration, although completion of only one method is sufficient to show compliance with the insulation requirements of Ch. ILHR 22.

Sample dwelling: Electrically heated single-family dwelling located in Dane County (Zone 3). Has 1,500 square feet and 186 linear feet of perimeter building thermal envelope. Garage is not heated. The 1,500-square foot basement wll be divided into a 575-square foot finished living space and a 925-square foot utility space. The basement ceiling is fully drywalled.

Gross above foundation wall = 8.13 feet (8 feet + 3/4-inch flooring + 3/4-inch ceiling) x 186 linear feet = 1,512.18 square feet
Wall window area = 150.33 square feet
Door area = 37.82 square feet
Box sill area = 0.81 feet (9-3/4 inches deep: sill, header, subfloor) x 186 linear feet = 150.66 square feet
Foundation wall height = 8 feet
Gross exposed foundation wall area = .67 feet (8 inches) x 186 feet = 124.62 square feet
Foundation wall window area = 8.30 square feet
Ceiling area = 1,500 square feet

Walls	
Wood bevel 1/2-inch x 8-inch siding	R = 0.81
1-inch extruded polystrene sheathing	R = 5.27
R19 Batt insulation	R = 19
2 x 6 framing, 24 inches O.C.	R = 6.875
1/2-inch drywall finish	R = 0.45
Ceiling	
2 x 6 framing, 24 inches O.C.	R = 6.875
Blown fiberglass insulation	R/inch = 2.5
Insulation in 5.5-inch cavity	R = 13.75
Insulation over both cavity and framing, 16 inches	R = 40
1/2-inch drywall finish	R = 0.45
Foundation	
8-inch masonry block	R = 1.72
2-inch extruded polystyrene	R = 10.54
Windows	
All triple glazed with 1/2-inch air spaces, U = .36	R = 2.8
Doors	
Insulated prime door	R = 2.12
Storm Door	R = 1.00
Total door R value	R = 3.12



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DILHR
Safety and Buildings Division
P.O. Box 7969
Madison, WI 53707

Submit completed worksheet with dwelling plans to local enforcing municipality.

ENERGY WORKSHEET
UNIFORM DWELLING CODE

PROJECT ADDRESS: SAMPLE - ZONE 3

BUILDER: ____________________ OWNER: ____________________

WORKSHEET COMPLETED BY: ____________________ DATE: ____________

Does dwelling unit have three kilowatts or more input capacity of permanently installed electrical space heating equipment?

☒ YES (see below) ☐ NO

If yes, then indicate infiltration control option, in addition to basic caulking:

_____ Full sealing per s. ILHR 22.13(3)(a)
__X__ Infiltration barrier per s. ILHR 22.13(3)(b)
_____ Blower door test per s. ILHR 22.13(2)(c) & (3)(c)

INSTRUCTIONS: This worksheet is a DILHR-approved method of showing compliance with the energy conservation standards of Chapter ILHR 22 of the Uniform Dwelling Code (UDC) which applies to one- and two-family dwellings and their additions built since December 1, 1978. It may be necessary for the user to purchase a copy of the UDC from State Document Sales, (608) 266-3358. Additional information is printed in the UDC Commentary, which is available for $5.00 from DILHR at the address at the top of this page.

All "R' and 'U' calculations must be carried to four places after the decimal point, rounded to three places. Linear dimensions must be carried to three places, rounded to two. Area and heat loss calculations may be rounded to the whole number.

Numbers in brackets, [1], refer to the footnotes printed on page 5.

Single copies of this worksheet are available free from DILHR at the above address. For multiple copies, contact DILHR for fee information. Earlier editions of this worksheet may be used, except that electrically heated dwellings require a worksheet reflecting the higher required U values.

Choice of Method

You have the choice of using the Accepted Practice Method or the System Design Method to show code compliance. For the simpler Accepted Practice Method, which is recommended for standard designs, complete Sections A., B., E., F., and H. You will be first calculating component areas, then your dwelling's code-allowed and other heat loss to determine your needed heating equipment capacity, and then comparing your planned insulation levels to the required insulation levels from the Appendix of the UDC.

For the System Design Method, which is recommended for alternative designs in which more insulation is installed in one component to offset less in another, complete Sections A. through F. You will be first calculating component areas, then the code-allowed heat loss, then component U- and R-values and then your calculated heat loss which you will compare to the code-allowed heat loss. You will also be calculating the allowable heating equipment capacity.

With either method, you will need to apply the stricter and slightly different standards shown for electrically-heated homes if you answered "YES" to the above question. For electrically heated homes, you must also complete Section G. to determine the required mechanical ventilation capacity.

SBD8-5518 (R. 01/95)

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A. AREA CALCULATIONS

Enter appropriate dimensions to obtain area values. Some calculations will not be necessary depending on home design and heating fuel. These calculated areas are referenced elsewhere on this worksheet, for example, A.1., A.2.

1. GROSS (INSULATED) ABOVE-FOUNDATION WALL AREA (Including doors, windows and box sills) 8.13 x 186 = 1512 0.81 x 186 = 151 1663 sq. ft.	4. GROSS EXPOSED FOUNDATION WALL AREA a. 0.67 x 186 = 125 sq. ft. Non-Electric Only: b. Multiply A.11. X .25 = ____ sq. ft. c. If A.4.a. is greater than A.4.b., then subtract b. from a. = ____ sq. ft.
2. WINDOW & PATIO DOOR AREA (sash/door area) a. In Above-Foundation Walls: 150 sq. ft. b. In Foundation Walls: 8 sq. ft. Total (a. + b.) = 158	5. FOUNDATION WALL AREA BETWEEN GRADE AND THREE FEET BELOW GRADE 3 x 186 = 558 sq. ft.
3. DOOR AREA IN ABOVE-FOUNDATION WALLS 38 sq. ft.	6. FOUNDATION WALL AREA MORE THAN THREE FEET BELOW GRADE 8' − 0.67' − 3.0' = 4.33' 4.33' x 186 = 805 sq. ft.

7. OPAQUE[1] ABOVE-FOUNDATION WALL AREA (A.1.- A.2.a.- A.3.) 1663 −173 =1452 sq. ft.	8. GROSS WALL AREA ABOVE GRADE (A.1. + A.4.a.) (Electric only) 1663 +125 =1788 sq. ft.	9. OPAQUE [1] EXPOSED FOUNDATION WALL AREA (A.4.a.- A.2.b.) 125 −16 =109 sq. ft.
10. WALL AREA BELOW GRADE (A.5. + A.6.) 558 +805 = 1363 sq. ft.	11. TOTAL FOUNDATION WALL AREA (A.4.a. + A.5. + A.6.) (Non-Electric) 125 +558 = 1488 sq. ft.	12. INSULATED ROOF OR CEILING AREA 28 x 45 = 1260 12 x 20 = 240 = 1500 sq. ft.
13. FLOOR AREA OVER UNHEATED SPACES (Less Than 50°) ____ sq. ft.	14. SLAB ON GRADE ____ lineal feet of slab perimeter	15. BASEMENT FLOOR AREA 1500 sq. ft.

B. CODE-ALLOWED HEAT LOSS

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Enter area values from Section A as notated and temperature differences per footnote 2 into this table and then multiply across by the electric or non-electric code-required U-value. Total the right column to find the total allowed heat loss.

COMPONENT	AREA FROM SECT. A	X	REQUIRED U-VALUE ☐ NON-ELEC	☒ ELECTRIC	X TEMP DIFFERENCE [2]	= HEAT LOSS BTU/HR
1. Gross Wall Above Grade (A.8.)(electric only)	1788		N/A	.080	85	12,158
2. Gross Above-Foundation Wall (A.1.)(non-elec)			.12	N/A		
3. Gross Exposed Foundation Wall (non-elec) a. Lesser of Area A.4.a. or A.4.b.			.25	N/A		
b. Area A.4.c. (if any)			.12	N/A		
4. Foundation Wall Between Grade And 3 Feet Below Grade (A.5.)	558		.113 [3]	.072 [3]	60	2,411
5. Foundation Wall More Than Three Feet Below Grade (A.6.)	805		.094 [3]	.048 [3]	60	2,318
6. Floors Over Unheated Spaces (A.13.)			.09	.055		
7. Roof or Ceiling (A.12.)	1,500		.029	.020	85	2,550
8. Slab On Grade (A.14.)	Lin. ft.		.51 'F' [4]	.51 'F' [4]		
9. Basement Floor (A.15.)	1500		.025	.025	60	2,250
TOTAL CODE - ALLOWED HEAT LOSS						21,687

C. SYSTEM DESIGN METHOD - ACTUAL 'U' VALUES OF YOUR HOME'S COMPONENTS

C.1. ABOVE-GRADE COMPONENTS - If applicable, check the appropriate typical component constructions listed below, and use the pre-calculated U values. If your wall construction is not listed, you may be able to obtain a pre-calculated U value from Table E-2 of the UDC Appendix. If your component construction is not listed here or in Table E-2, you will need to enter R-values for the different layers of building materials from Table A-4 of the UDC Appendix, ASHRAE Fundamentals Manual or manufacturer's specifications. Total them across and then determine the U-value by taking the reciprocal (1/R) of the total R-value.

COMPONENT	CAVITY OR SOLID IF APPLICABLE	EXT. AIR FILM *	EXT. FINISH	SHEATHING	INSULATION OVER FRAMING	FRAMING OR SOLID	INSULATION WITHIN CAVITY	INTERIOR FINISH	INT. AIR FILM	TOTAL 'R-VALUE'	'U-VALUE'
Above-Foundation Walls	Cavity	.17	0.81	5.27			19	0.45	.68	26.38	0.038
	Solid	.17	0.81	5.27		6.88		0.45	.68	14.26	0.070
☐ 2X4, 16" O.C., R-11 batt, R-1 board: U - .081 ☐ 2X4, 16" O.C., R-11 batt, R-5 board: U - .060											
☐ 2X6, 16" O.C., R-19 batt, R-1 board: U - .055 ☐ 2X6, 16" O.C., R-19 batt, R-5 board: U - .044											
☐ Other - describe: U - from Table E-2											
Exposed Foundation	Cavity	.17							.68		
	Solid	.17		10.54		1.72			.68	13.11	0.076
☐ Masonry or concrete wall without insulation: U - 1.0 ☐ Masonry or concrete wall with R-5 insulation: U - .167											
☐ Masonry or concrete wall with R-10 insulation insulation board or R-11 insulation batt and 2X4s: U - .091											
☐ Other - describe: U - from Table E-2											
Roof or ceiling	Cavity	.61							.61		
	Solid	.61							.61		
☐ 2X4 truss, 24" O.C., with R-38 insulation: U - .029 ☒ 2X4 truss, 24" O.C., with R-52 insulation: U - .020											
☐ 2X12 cathedral ceiling, 16" O.C., with R-38 insulation: U - .027											
Floor Over Unheated Space	Cavity	.17							.92		
	Solid	.17							.92		
☐ 2X10 joists, 16" O.C., R-19 batt: U - .045											

* Air Film R-Values

LOCATION	HEAT FLOW DIRECTION Upwards	Horizontal	Downwards
EXTERIOR	.17	.17	.17
INTERIOR	.61	.68	.92

C.2. BELOW-GRADE AND SLAB-ON-GRADE COMPONENTS - Check appropriate boxes for planned type of construction to determine precalculated overall 'U-value' including air films, wall, insulation, soil and cavity/solid differences. Slab on grade F-values are per lineal foot of slab perimeter.

COMPONENT TYPE	GRADE TO THREE FEET BELOW GRADE	MORE THAN THREE FT. BELOW GRADE
☐ Masonry or concrete wall without insulation	.288	.094
☐ Concrete block with insulated cores	.113	.063
☐ Masonry or concrete wall with R-5 insulation board	.113	.063
☐ Masonry or concrete wall with R-10 insulation board or R-11 insulation batt and 2x4's	.072	.048
☐ Permanent wood foundation with R-19 batt	.043	.034
☐ Basement floor without insulation	.025	.025
☐ Basement floor with R-5 insulation	.022	.022
☐ Other (describe)		
SLAB-ON-GRADE (or within 2 feet of grade)	UNHEATED SLAB	HEATED SLAB
☐ Slab-on-grade without insulation	.81 (F-value)	2.73 (F-value)
☐ Slab-on-grade with R-5 insulation for 48" total horizontal and vertical application	.56 (F-value)	.90 (F-value)
☐ Slab-on-Grade with R-10 insulation board for 48" total application	.51 (f-value)	.82 (F-value)

C.3. WINDOWS AND DOORS - See Tables A-5 and A-6 of UDC Appendix for U-values. You may use manufacturer's specifications for window and glazed door values if they are per NFRC Std 100 or Window 3.1.

D. SYSTEM DESIGN METHOD - CALCULATED ENVELOPE HEAT LOSS OF YOUR HOME

Enter values into table from elsewhere on this worksheet and multiply across to find the actual heat loss of each component. If using precalculated component U-values, do not calculate cavity and solid figures or apply wood frame factors. Total component heat loss figures in right column to find total envelope heat loss.

COMPONENT	CAVITY OR SOLID IF APPLICABLE	AREA FROM SECT. A.	X	WOOD FRAME FACTOR **	X	ACTUAL 'U' VALUE FROM SECT. C.	X	TEMP DIFFERENCE [2]	=	HEAT LOSS BTU/HR
Opaque Above-Foundation Wall (A. 7.)	Cavity	1452		0.78		0.038		85		3658
	Solid			0.22		0.070				1900
Opaque Exposed Foundation Wall (A. 9.)	Cavity	109				0.076		85		704
	Solid									
Foundation Between Grade and Three Feet Below Grade (A. 5.)	Cavity	558				0.072		60		2411
	Solid									
Foundation Wall More Than Three Feet Below Grade (A. 6.)	Cavity	805				0.048		60		2318
	Solid									
Above-Foundation Windows (A. 2. a.)	--------	158		--------		0.360		85		4834
Foundation Windows (A.2.b.)	--------			--------						
Doors (A.3.)	--------	38		--------		0.321		85		1037
Roof or Ceiling (A. 12.)	Cavity	1500				0.20		85		2550
	Solid									
Floor Over Unheated Spaces (A. 13.)	Cavity									
	Solid									
Basement Floor (A. 15.)	Cavity	1500				0.025		60		2250
	Solid									
Slab On Grade (A. 14.)	--------	Lin. ft.		--------		F-Val.				
				TOTAL CALCULATED ENVELOPE HEAT LOSS - May not exceed Total Code Allowed Heat Loss in Sect. B. by more than 1%						21,662

** Adjustment Factors For Wood-Framed Components

SPACING OF FRAMING MEMBERS	STUD WALLS		JOISTS/RAFTERS	
	CAVITY	SOLID	CAVITY	SOLID
12"	.70	.30	.86	.14
16"	.75	.25	.90	.10
24"	.78	.22	.93	.07

Also see Part C of UDC Appendix Table A-5 for window framing adjustment factors.

E. HEAT LOSS BY AIR INFILTRATION (for furnace sizing)

Enter appropriate values. An air change rate of between 0.25 and 1.00 per hour is recommended depending on tightness of construction.

FLOOR LEVEL	AREA	X	HEIGHT	=	VOLUME	X	CONSTANT	X	TEMPERATURE DIFFERENCE [2]	X	AIR CHANGES PER HOUR	=	HEAT LOSS BTU/HR
Basement	1500		8		12,000		.018		85		.5		9180
Level 1	1500		8		12,000		.018		85		.5		9180
Level 2							.018						
Level 3							.018						
Total Conditioned Dwelling Volume					24,000				INFILTRATION HEAT LOSS				18,360

F. HEATING EQUIPMENT SIZING

Enter appropriate value to determine the maximum and minimum allowable heating equipment capacity in BTU's/HR. [5]

	Minimum	Maximum
System Design Method: Calculated Heat Loss from Sect. D. or Accepted Practice Method: Code-Allowed Heat Loss from Sect. B.	21,662	---------
Code-Allowed Heat Loss (from Sect. B.)	---------	21,687
Infiltration Heat Loss (from Sect. E.)	+ 18,360	+ 18,360
TOTAL DWELLING HEAT LOSS (total of above)	= 40,022	= 40,047
Allowable Heating Equipment Size Margin Multiplier	X 1.0	X 1.15
ALLOWABLE HEATING EQUIPMENT OUTPUT SIZE RANGE	= 40,022	= 46,054 [6]
Planned Furnace Output Or Boiler IBR Rating	50,000	

G. MECHANICAL VENTILATION SIZING

For electrically heated dwellings only, enter appropriate values to determine minimum cubic feet per minute (CFM) fan output to meet one-half air exchange per hour requirement.

1. Dwelling volume from Sect. E.	24,000
2. Less volume of non-living area; area: (925) X height: (8) =	- 7,400
3. Less volume of dead air spaces (cabinets, walls, etc - approx. 20% of living space volume)	- 3,400
4. Net volume of living area (total of above)	= 13,200
5. Minimum cubic feet of air changed per hour (multiply line 4 by 0.5)	= 6,600
6. MINIMUM REQUIRED MECHANICAL VENTILATION IN CFM's (divide line 5 by 60)	= 110

Footnotes:

[1] Opaque wall area is wall area minus opening areas of doors and windows.

[2] Temperature Difference = Inside design temperature of 70° minus outside design temperature from Table 22.04-8 of the UDC. Basement inside temperature may be taken between 50° and 70°. Temperature difference for transmission heat losses only (not infiltration losses) of below-grade spaces of basements is inside temperature minus 10°, disregarding outside temperature. If the basement ceiling is insulated, then the basement is considered unheated and the heat loss from the above heated space through the basement ceiling should be calculated using an outside temperature of 45°.

[3] These below-grade U-values have the insulating value of the soil added to the code-required U-values which apply to the building materials only. See sect. C.2. for typical insulated component U-values.

[4] These slab-on-grade F-values are derived from the code-required U-values and include the heat loss through the edge and body of the slab. See sect. C.2. Temperature difference is the same as for above-grade spaces.

[5] For building additions, show that the existing heating equipment, if used to also heat the addition, is large enough. To do so, you must calculate the heat loss of the whole building.

[6] If desired manufacturer does not have a furnace of this size, then a designer may select the manufacturer's next larger size.

H. ACCEPTED PRACTICE METHOD

For completion of the accepted practice method, please refer to the Appendix Tables A-l, 2 and 3 and E-l, 2 and 3 of the Uniform Dwelling Code (UDC). Complete Subsection H.1. if your home is heated with other than electricity. Complete Subsection H.2. if your home is electrically heated. Area figures should be calculated in Section A. and are referenced below.

SUBSECTION H.1. Non-Electrically Heated Homes Only

WALLS ABOVE FOUNDATION WALL INCLUDING BOXSILL, USE TABLE A-1	MINIMUM ABOVE-FDTN WINDOWS: ☐ Single w/storm ☐ Insulated glass ☐ Triple pane MINIMUM DOORS: ☐ Insulated ☐ Solid Wood ☐ Uninsulated w/storm SIDING: ☐ Wood (R-.77) ☐ Alum. (R-1.82) ☐ Other: R-____ PLANNED INSULATION TYPE AND R-VALUE: ________ PERMITTED WINDOW AND DOOR AREA: ____ % ____ (Above Foundation Window & Door Area (A.2.a. + A.3.)) ÷ ____ (Gross Above-Foundation Wall Area (A.1.)) X 100% = ____ % (% Planned Window and Door Area)
EXPOSED FOUNDATION WALL, USE TABLE A-2	BASEMENT WINDOWS: ☐ Single-glazed OR ☐ Single w/storm or insulated glass PLANNED INSULATION TYPE AND R-VALUE: ________ If no number entered in A.4.c., then enter Percent Permitted Window Area from Table A-2, U_o = .25: ____ % If number entered in A.4.c., then calculate: [(____ (Area A.4.b.) X ____ %) (% Window from Table A-2, U_o = .25) + (____ (Area A.4.c.) X ____ %) (% Window from Table A-2, U_o = .12)] ÷ ____ (Area A.4.a.) = ____ % (% Permitted Window Area) ____ (Basement Window Area (A.2.b)) ÷ ____ (Exposed Fndtn. Wall Area (A.4.a.)) X 100 % = ____ % (% Planned Window Area)
ROOF OR CEILING, USE TABLE A-3	PLANNED INSULATION TYPE: ____ R-VALUE PER INCH: ____ REQUIRED THICKNESS: ____ Inches in cavity (R-38) ____ Inches Over Framing (R-19)
FOUNDATION WALL, GRADE TO 3 FEET DOWN	PLANNED INSULATION TYPE AND R-VALUE: ________ (MINIMUM R-5 INSULATION)

SUBSECTION H.2. Electrically Heated Homes Only

Completed for demonstration purposes. Normally only complete the system design method or accepted practice method

WALLS ABOVE FOUNDATION INCLUDING BOX-SILL, USE TABLES E-1 AND E-2	ALL THESE MEASURES REQUIRED: ☐ ALL WINDOWS TRIPLE-GLAZED ☐ EXPOSED FOUNDATION INSULATED TO R-10.54 ☐ DOORS INSULATED TO R-8 189 (Total Window Area (A.2.a. + b.)) ÷ 1788 (Above Grade Wall Area (A.8.)) X 100 % = 10.6 % (% Window Area) 109 (Opaque Exposed Foundation Area (A.9.)) ÷ 1788 (Above-Grade Wall Area (A.8.)) X 100 % = 6.1 % (% Opaque Exposed Foundation Wall) REQUIRED ABOVE FOUNDATION WALL U-VALUE (FROM TABLE E-1): .044 PLANNED WALL CONSTRUCTION: 2 x 6 24" o.c. foamboard R-19 batt, R5 U-VALUE FROM TABLE E-2: .043
ROOF OR CEILING, USE TABLE E-3	PLANNED INSULATION TYPE: blown fiberglass R-VALUE PER INCH: 2.5 REQUIRED THICKNESS FROM TABLE E-3: 20.0 Inches
FOUNDATION WALL FOR FULL HEIGHT	PLANNED INSULATION TYPE AND R-VALUE: 2" XEPS R10.5 (MINIMUM R-10 INSULATION)

TABLE A-1

WALL INSULATION GUIDE

(Based on U_0 requirements above the foundation wall for non-electrically heated dwellings)

INSULATION TYPE	MAXIMUM PERCENT WINDOW AND DOOR AREA ALLOWABLE FOR INSULATION TYPE U_0 = .12	
	⅝ 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_0 = .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_0 = .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_0 = .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

TABLE E-1 - DIRECTIONS FOR USE

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.

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

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

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, the insulation level may be calculated by the method illustrated following Tables E-1 and E-2.

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

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.
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.

MANUAL CALCULATION METHOD

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.

% 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.

$$\frac{Uo - (Uw \times \%w) - (Ud \times \%d) - (Uf \times \%f)}{\%_{wall}} = U_{wall}$$

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-3 shows the U-values obtainable from different insulation materials and framing types.

TABLE E-3 DIRECTIONS FOR USE

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 perlite 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, you may calculate the required U-value as shown after Table E-3.

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)

MANUAL CALCULATION METHOD

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

A_o = 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"C24" 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-R/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 ft × 1.17 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:

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

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)

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

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

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

Material	Description		Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
	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	—
	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, 12% 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	3 in.	—	—	1.27
	aggregate(expanded	4 in.	—	—	1.50
	shale, clay, slate	8 in.	—	—	2.00
	or slag; pumice)	12 in.	—	—	2.27
	Concrete blocks, rectangular core				
	Sand & gravel aggregate				
	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

Material	Description		Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
	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	3/8 in.	—	—	0.08
	Sand aggregate	3/4 in.	—	—	0.15
	Gypsum plaster:				
	Lightweight aggregate	1/2 in.	45	—	0.32
	Lightweight aggregate	5/8 in.	45	—	0.39
	Lightweight aggregate on metal lath	3/4 in.	—	—	0.47
	Perlite aggregate		45	0.67	—
	Sand aggregate		105	0.18	—
	Sand aggregate	1/2 in.	105	—	0.09
	Sand aggregate	5/8 in.	105	—	0.11
	Sand aggregate on metal lath	3/4 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	3/8 in	70	—	0.33
	Slate	1/2 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, 1/4" lapped		—	—	0.21
	Asphalt roll siding		—	—	0.15
	Asphalt insulating siding (1/2" bd.)		—	—	1.46
	Wood drop 1 x 8"		—	—	0.79
	Wood bevel, 1/2" x 8" lapped		—	—	0.81
	Wood bevel, 3/4" x 10" lapped		—	—	1.05
	Wood plywood 3/8" lapped		—	—	0.59
	Aluminum or steel, over sheathing, hollow-backed		—	—	0.61
	Insulating-board backed nominal 3/8"		—	—	1.82
	Insulating-board backed nominal 3/8" 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	1/8 in.	—	—	0.28
	Terrazzo	1 in.	—	—	0.08
	Tile-asphalt, linoleum, vinyl, rubber		—	—	0.05
	Wood, hardwood finish	3/4 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	—

Material	Description		Density (lb per cu ft)	Per inch thickness R-Value	For thickness listed R-Value
	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
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 7¾"	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	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

*Reprinted with permission from ASHRAE Handbook of Fundamentals.

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).

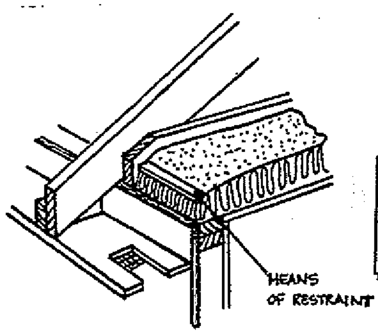


Fig. 1a

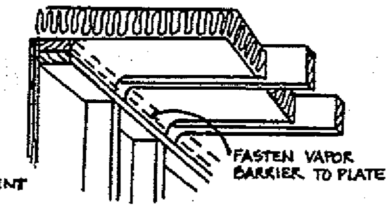


Fig. 1b

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).

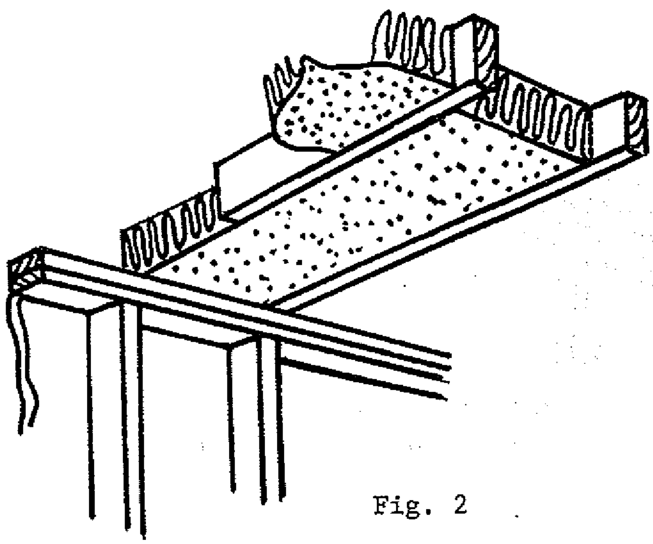


Fig. 2

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.

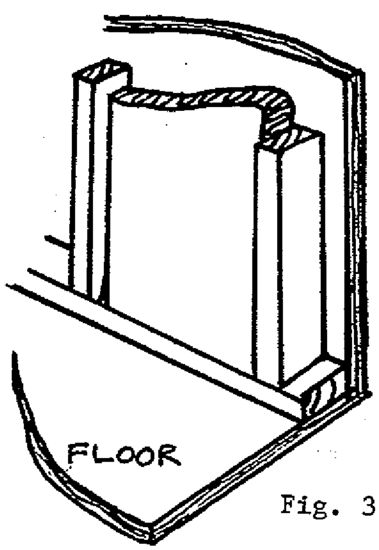


Fig. 3

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.

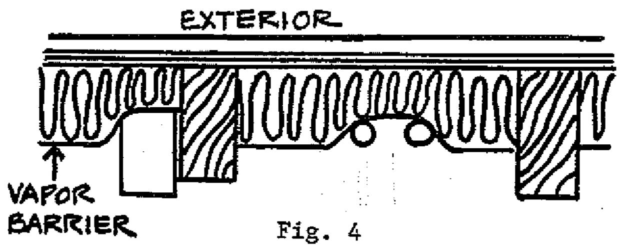


Fig. 4

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

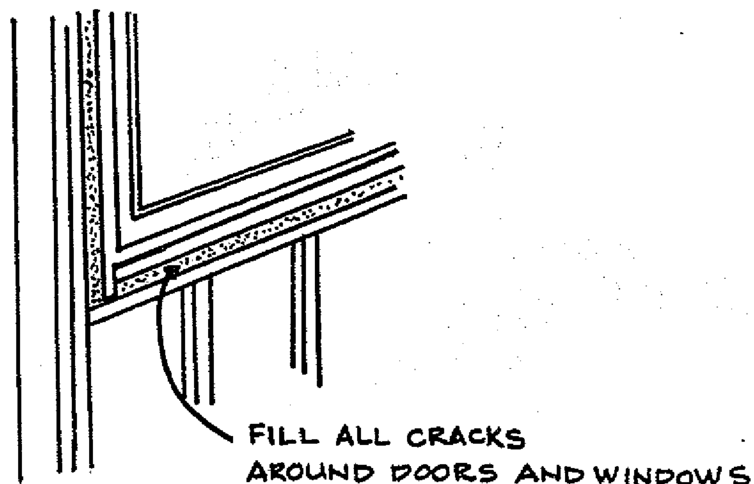


Fig. 5

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

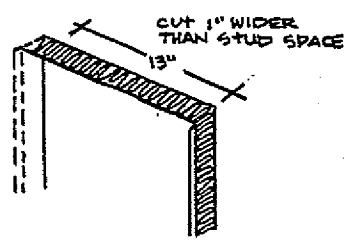


Fig. 6a

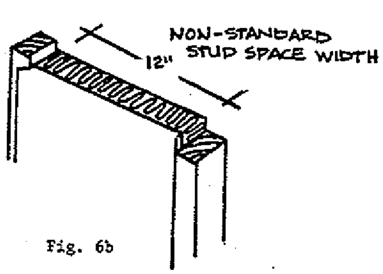


Fig. 6b

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.

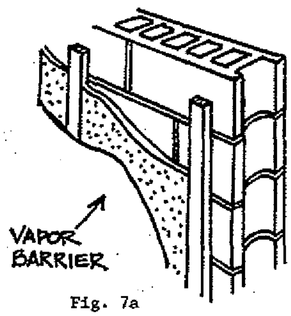


Fig. 7a

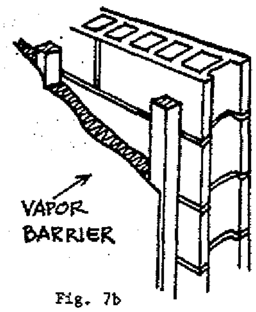


Fig. 7b

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.

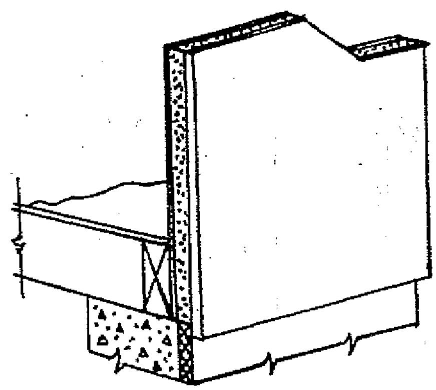


Fig. 8

Rigid insulation in stress skin panels (Fig. 8) may also be used to insulate walls, ceilings and roofs. .

Floor and Crawl Spaces

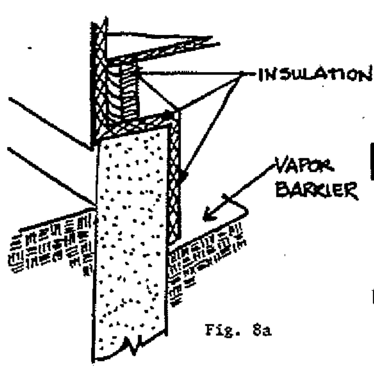


Fig. 8a

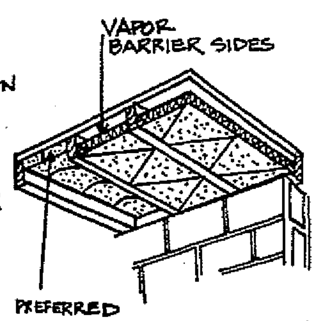


Fig. 8b

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.

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.

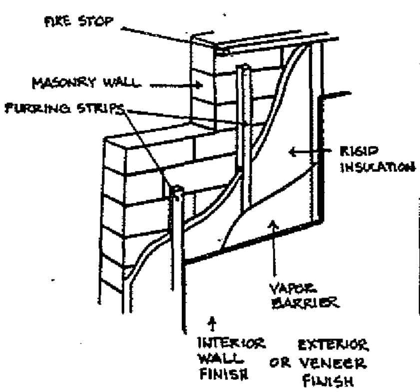


Fig. 9a

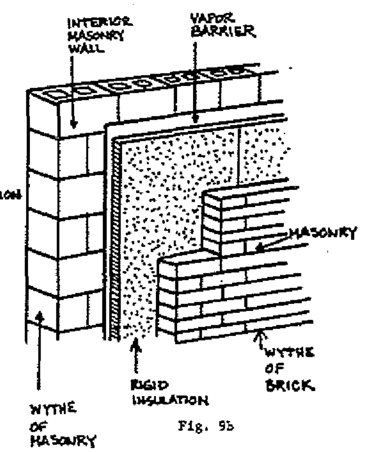


Fig. 9b

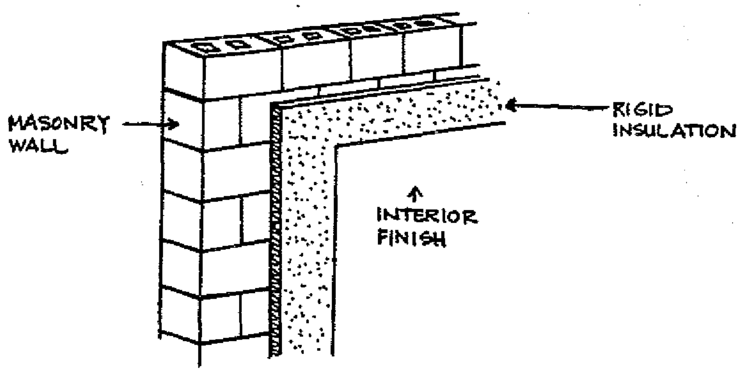


Fig. 9c

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.

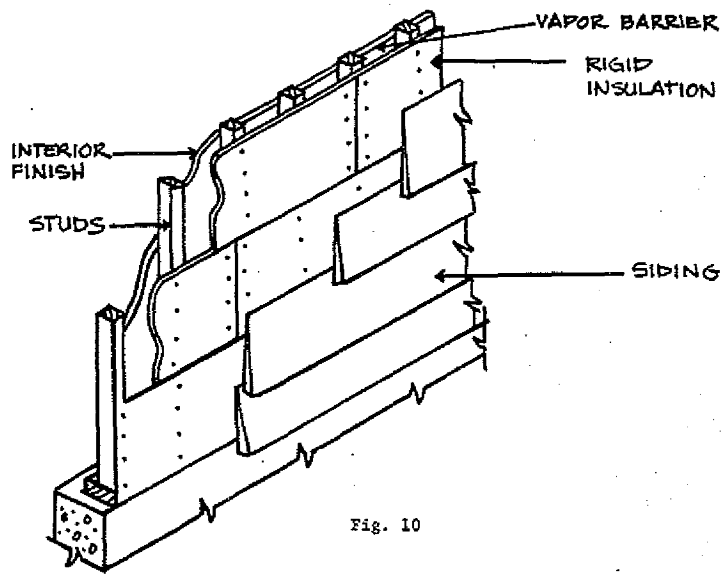


Fig. 10

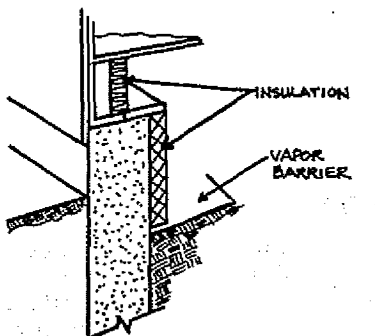


Fig. 11a

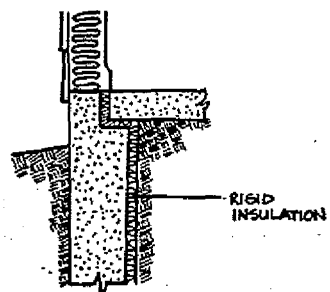


Fig. 11b

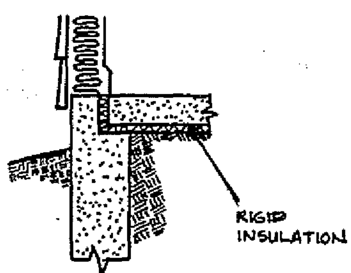


Fig. 11c

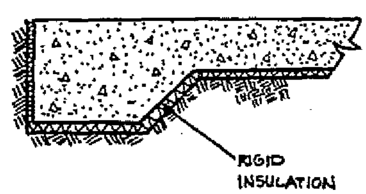


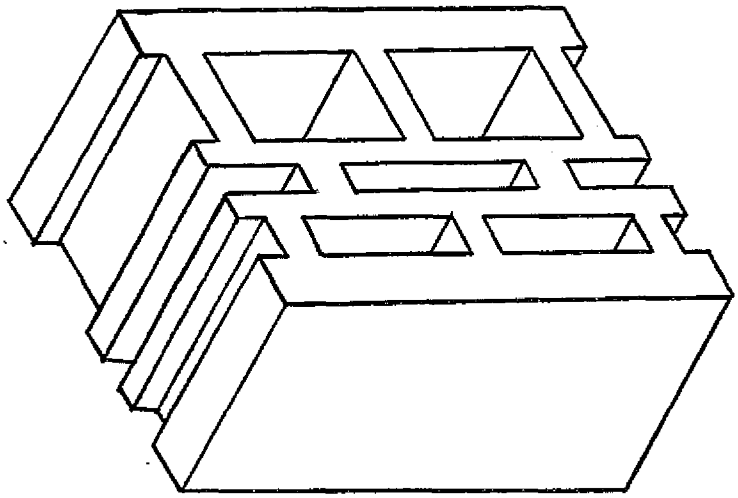
Fig. 11d

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	5″	59 sq. ft. (40 lb. bag)	17
Glass fiber	8″	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 a reffective 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	3″
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 RETARDERS

Vapor retarders are used in conjunction with insulation to decrease the change of moisture condensation inside the building insulation. Vapor retarders 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 retarder 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 retarder.

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 more fuel 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

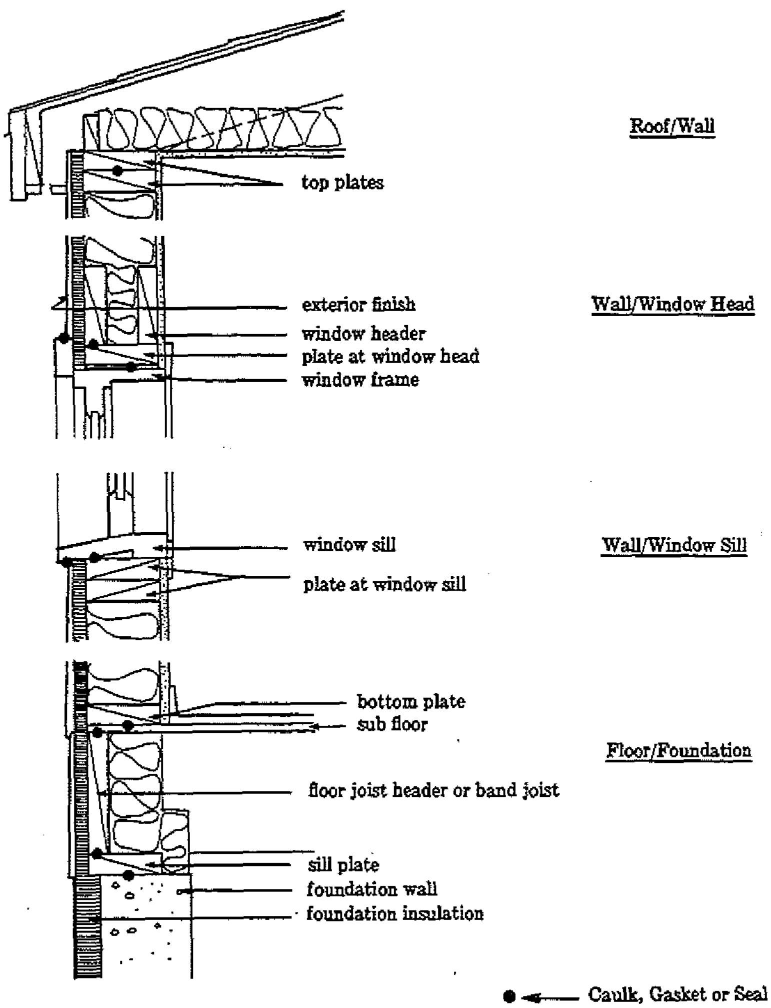
Winter: During the winter it is desirable to have humidity in the air in order to prevent the nostrils from becoming dry, furniture from cracking, etc. However, from an energy standpoint, it is desirable to keep the relative humidity low; the trade-off is at about 30%.

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%.

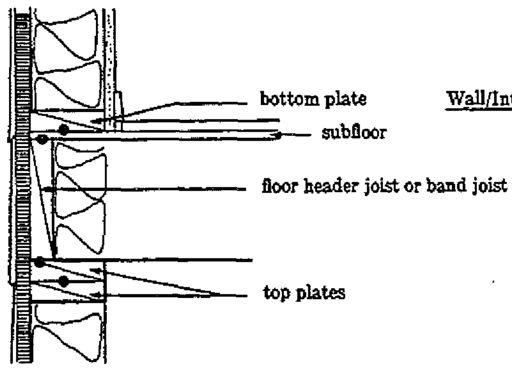
ILLUSTRATIONS OF EXTERIOR OPENINGS IN THE THERMAL ENVELOPE

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).

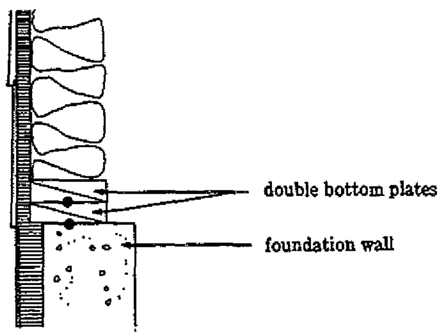
ILHR 22.13 Infiltration Control for Electrically Heated Homes



ILHR 22.13 Infiltration Control for Electrically Heated Homes (continued)



Wall/Intermediate Floor



Wall/Foundation