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Thermal Design Guide for Exterior Walls

Steel in Residential Construction Advisory Group

THERMAL DESIGN GUIDE FOR EXTERIOR WALLS RG-9405

technical data

Framing Details

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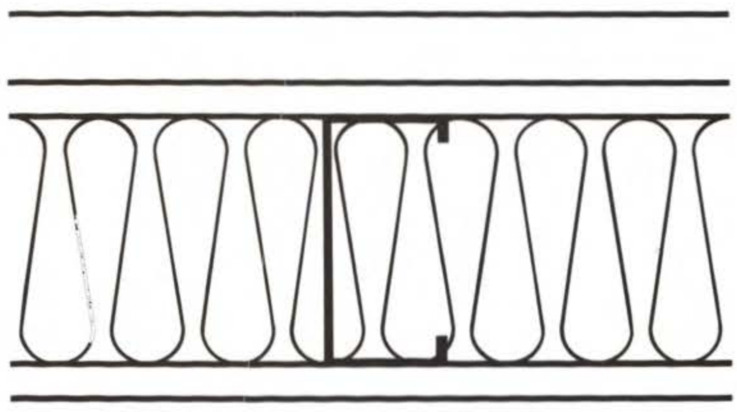

Steel in Residential Construction Advisory Group

American Iron and Steel Institute
1101 17th Street, NW
Washington, DC 20036-4700

Thermal Design Guide for Exterior Walls
January 1995

INTRODUCTION

This publication was developed by the American Iron and Steel Institute with guidance from the AISI Residential Advisory Group. It is intended to provide designers and contractors with guidance on thermal design of buildings that utilize cold-formed steel framing members. AISI believes that the information contained in this publication substantially represents industry practice and related scientific and technical information, but the information is not intended to represent an official position of AISI or to restrict or exclude any other construction or design techniques.

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January 1995

Thermal Design Guide for Exterior Walls

Selection of Wall Insulation — R-Values for Typical Construction

The resistance to heat flow through a wall is usually quantified by a property known as the thermal resistance or R-value. Because walls typically are comprised of various materials (studs, tracks, cavity insulation, sheathing, etc.), an effective R-value must be determined for the system. To develop R-values for typical steel framed construction, the AISI sponsored research at the National Association of Home Builders (NAHB) Research Center. The project included full scale calibrated hot box tests (ASTM C976) conducted by Holometrix, Inc., analysis by NAHB Research Center, and thermal modeling by the Oak Ridge National Laboratory (ORNL). This design information summary has been prepared based on the results of those investigations.

The research showed that the wall R-value is not affected much by the thickness of the steel stud. Because the stud web thicknesses are small compared to other dimensions, the heat conducted through them is somewhat limited. Where higher R-values are required, the use of an exterior insulative sheathing such as extruded polystyrene or poly-isocianurate foam forms an effective thermal break and increases R-values significantly. Where such insulative sheathings are used, calculation by the ASHRAE Zone Method tends to underestimate the R-value unless the newly developed zone correction factors described herein are used. In general, the effect of a stud in a wall is to act as a "thermal bridge," that is, it provides a path for conducting heat more rapidly than a path midway between studs. Both wood studs and steel studs provide thermal bridges as illustrated in Figure 1. Part of the heat flows directly through the cavity, while part flows laterally toward the stud and combines with that flowing directly through the stud. Either type of wall can be designed to provide the desired thermal performance.

1. Test Information

A total of 23 tests were conducted on 8 x 8 ft. specimens by Holometrix, Inc. in an ASTM AC976 Calibrated Hot Box facility. All tests were run at 45°F mean temperature, 70°F on the inside and 20°F on the outside, except as noted. All walls had C-section steel studs, 0.033 or 0.043 in. thick, joined to top and bottom tracks with #6, S-12, 5/16-in. long, pan head screws. (The tracks were eliminated for one test as subsequently noted.) Full width fiberglass batts were placed in the cavity. On the warm side, each wall had 1/2 in. gypsum wall board installed over a 4 mil polyethylene vapor barrier with #6, 1-in. long, bugle head screws. Figure 2 shows a schematic of the test specimens. Construction details and resulting effective R-values for the walls are summarized on the following page and presented in more detail in the Appendix.

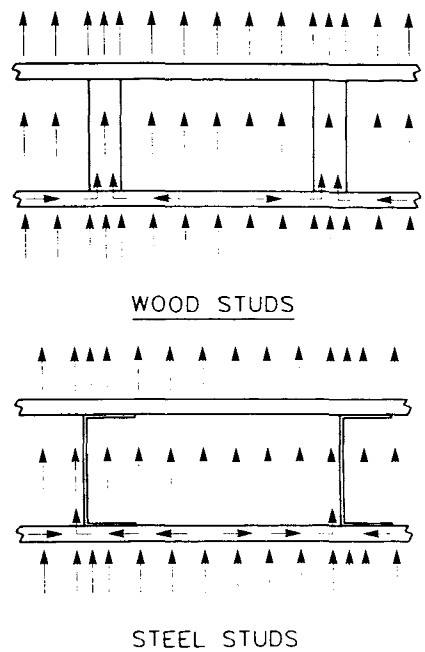


Figure 1. Heat flow through walls

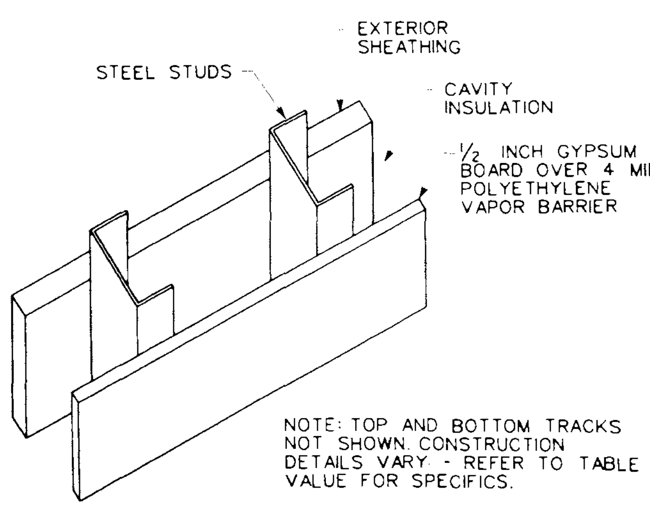


Figure 2. Schematic of test specimen

Tests Conducted						
Test No.	Stud Size, in.	Stud Spacing, in.	Cavity Insulation	Exterior Sheathing	Special Detail	R-Value
A1	$1^5/8$ x $3^5/8$ x 0.043	24	R-11	1/2" plywood		7.9
A1a	do.	24	R-11	do.	15 mph wind	7.8
A1b	do.	24	R-11	do.	75°F mean	7.4
A2	do.	24	R-11	1" XPS		13.7
A4	do.	24	R-11	1/2" gypsum + 1" XPS		13.9
A5	do.	24	R-11	1/2" XPS		11.4
A6	do.	24	R-11	2" XPS		18.9
A7	do.	24	R-11	1/2" plywood 7/8" hats		9.3
A8	do.	24	R-11	1" XPS + 7/8" hats		14.4
A9	do.	24	R-11	1/2" plywood + foam tape		8.4
B1	do.	12	R-11	1/2" plywood		6.8
B2	do.	12	R-11	1" XPS		12.4
C1	$1^5/8$ x $3^5/8$ x 0.033	24	R-11	1/2" plywood		8.3
C2	do.	24	R-11	1" XPS		13.9
C3	do.	24	R-11	1/2" plywood + 1" XPS		14.5
C4	do.	24	R-11	1/2" plywood	two layers w/ 1/2" air space	13.3
D1	$1^5/8$ x 6 x 0.043	24	R-19	1/2" plywood		10.1
D2	do.	24	R-19	1" XPS		16.2
D3	do.	24	R-19	1" polyiso.		17.1
D4	do.	48	R-19	1/2" plywood + 7/8" hats	int. gyp. over 7/8" hats	12.4
E1	$2^1/2$ x $3^5/8$ x 0.043	24	R-11	1" XPS		13.5
F1	$1^5/8$ x $3^5/8$ x 0.043	24	R-15	1" XPS		15.6
F2	$1^5/8$ x $3^5/8$ x 0.033	24	R-13	1" XPS + 3/4" stucco	no tracks	15.7

2. Determination of R-Value

The effective R-value for the wall may be determined by either of two methods: (1.) calculations according to the ASHRAE zone method but using zone factors developed by ORNL for walls with steel framing, (2.) directly from a chart developed by the NAHB Research Center from a parametric study. Each of these is based on the test data mentioned above. Their use is illustrated below.

2.1 ASHRAE Zone Method with ORNL Zone Factors

When calculating R-factors by the ASHRAE method, a typical wall section is divided into two zones, Figure 3. Zone A is the wall section with steel framing and Zone B is the wall section without steel framing. To improve the accuracy of this method for steel-framed walls, the ORNL developed a chart of zone factors for use in calculating the width of the thermal bridge. The zone factor chart, Figure 4, increases

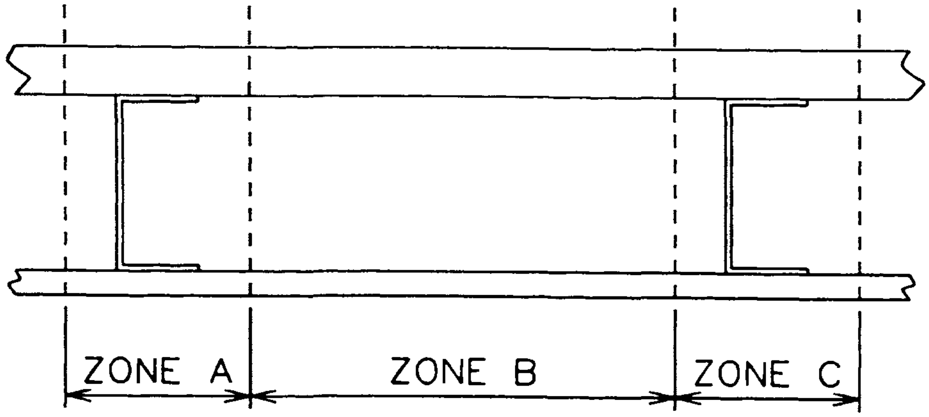


Figure 3. Wall zones for thermal calculations

the accuracy of the ASHRAE zone method from ±15% to ±2%. It is based on finite difference computer modeling of over 1000 walls and correction with test data. It use is illustrated in the following example.

Wall Construction

Inside finish: 0.50 in. gypsum wallboard

Cavity insulation: R-11 full width fiberglass batts.

Outside finish: 1 in. extruded polystyrene (R-5) and 0.50 in. hardboard siding. Steel framing: Studs 3.5 x 1.25 x 0.033 in. @ 24 in. spacing. To account for tracks and window framing, as well as studs, assume steel framing is 12% of the thermal transmission area. This percentage will be different for other stud spacings.

1. Tabulate thermal properties from ASHRAE Handbook or manufacturers' data. The following definitions and units apply:

Thermal Resistance = R = (hr · ft^2 · °F/Btu)
Thermal Conductance = C = 1/R = (Btu/hr · ft^2 · °F)
Thermal Conductivity = k = thickness x C = (Btu · in/hr · ft^2 · °F)

Component	R	C	k
Air (Outside @ 15 mph)	0.17	6.00	—
Hardboard siding	0.67	1.50	—
Extruded polystyrene	5.0	0.20	1x0.20=0.20
Cavity insulation	11	0.091	3.5x0.091=0.318
Steel	—	—	314.4
Gypsum	0.45	2.22	—
Air (Outside @ 15 mph)	0.61	1.63	—

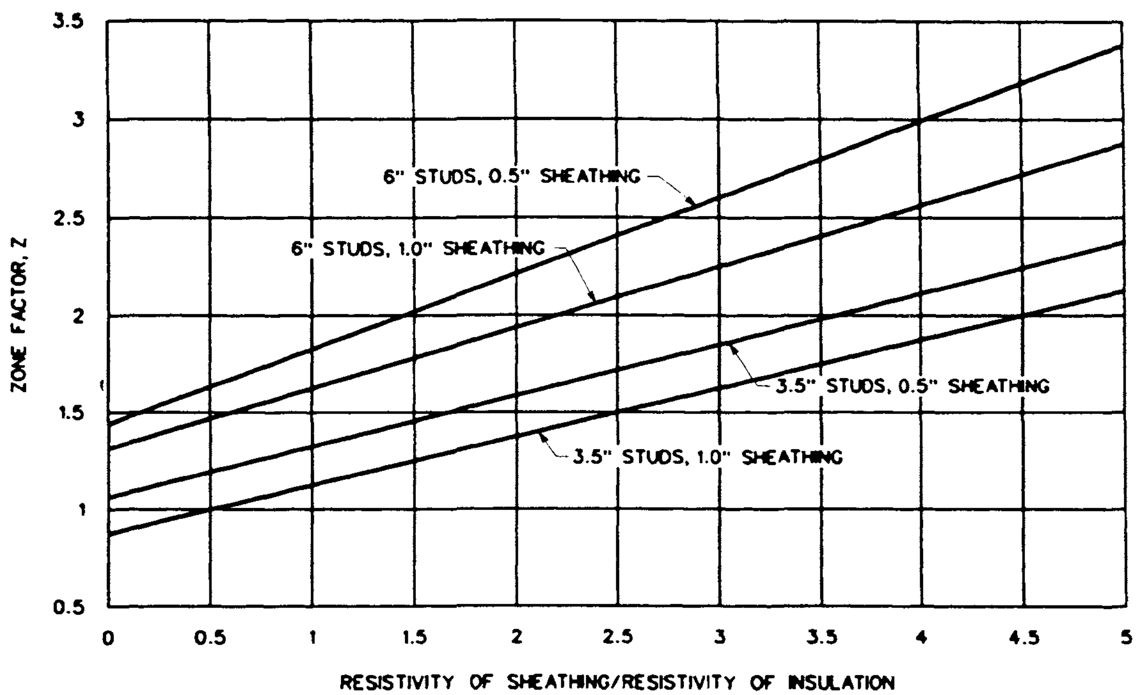


Figure 4. ORNL factors for ASHRAE zone method

2. Adjust stud spacing to account for effect of other framing using the 12% factor.

Adjusted spacing = flange width/framing percentage factor
= 1.25/.12 = 10.4 in.

3. Calculate basic area of transmittance.

Basic area = adjusted spacing (ft) * 1 ft height
= (10.4/12) * 1 = 0.87 ft^2

4. Calculate zone areas.

(a.) Find zone factor from chart, Figure 1.

Resistivity = 1/conductivity

$$\frac{\text{Resistivity of sheathing}}{\text{Resistivity of insulation}} = \frac{1/0.200}{1/0.318} = 1.6$$

From Figure 4, intersect the vertical line for 1.6 with the solid sloping line for 3.5 in. studs with 1 in. sheathing. Read the zone factor from the left of the chart as 1.3.

(b.) Calculate the thermal bridge width for the stud as the larger of the values for the inside path (through 0.50 in. gypsum) and the outside path (through 1 in. extruded polystyrene and 0.50 in. hardboard siding) using the following equation (see Figure 5):

$$W = m + Z * d$$

where W = thermal bridge width
m = stud flange width
Z = zone factor
d = distance from inside or outside surface to stud flange

Inside width = 1.25 + 1.3 * 0.50 = 1.90 in.
Outside width = 1.25 + 1.3 * (1.00 + 0.50) = 3.20 in.
Use the larger value, W = 3.20 in.

(c.) Calculate areas of Zone A (wall section with steel framing) and Zone B (wall section without steel framing).

Area Zone A = W (ft) * 1 ft height
= (3.2/12) * 1 = 0.27 ft^2

Area Zone B = Basic area – Area Zone A
= 0.87 – 0.27 = 0.60 ft^2

5. Determine area transmittance (UA) for Zone A and Zone B.

(a.) Zone A. The area conductance (CA, Btu/hr · °F) of each component of the wall section is calculated as the area (ft^2) times the thermal conductance (Btu/hr · ft^2 · °F). This is converted to area resistance (R/A, hr · °F/Btu), then summed to obtain total zone resistance. The reciprocal of the resistance is the area transmittance (UA, Btu/hr · °F). Note that the steel web and the insulation in the stud cavity are treated together. Their conductivity values must be divided by the web depth (3.42 in.), and their CA values must be summed to calculate the resistance.

	Area Transmittance, Zone A	
Component	**Area x Conductance = CA**	**Resistance = 1/CA = R/A**
Outside air @ 15 mph	0.27 * 6.0 = 1.62	1/1.62 = 0.62
Hardboard siding, 1/2 in.	0.27 * 1.5 = 0.41	1/0.41 = 2.44
Extruded polystyrene, 1 in.	0.27 * 0.20 = 0.05	1/.05 = 20.00
Steel web	(0.033/12) * 314/3.42 = 0.253	1/(0.253+0.025) = 3.60
Insulation	0.27 * 0.318/3.42 = 0.025	
Gypsum	0.27 * 2.22 = 0.60	1/0.60 = 1.67
Inside air	0.27 * 1.63 = 0.44	1/0.44 = 2.27
	Total R/A =	30.6
	UA = 1/30.3 =	0.033

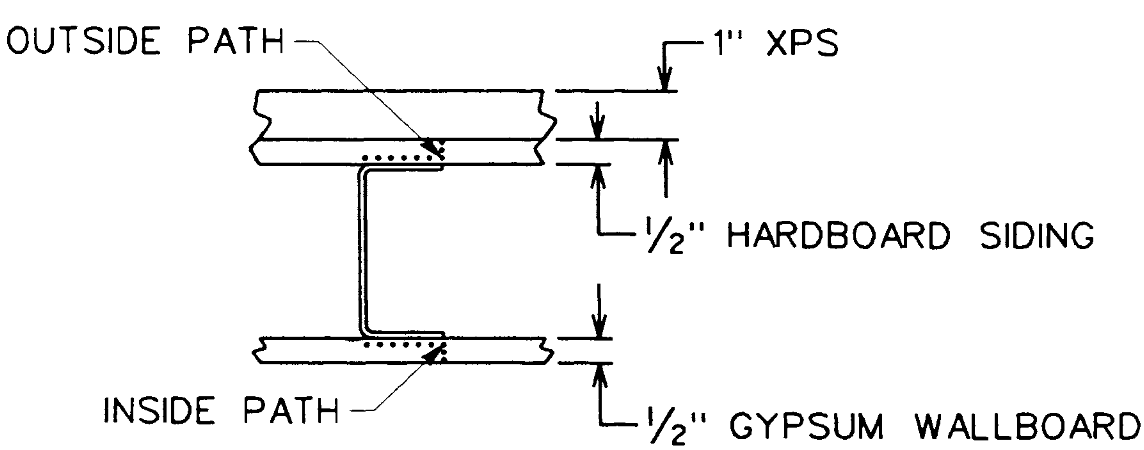


Figure 5. Paths for thermal bridge calculation

(b.) Zone B. The calculations for Zone B are simplified because there is no framing in this zone. Sum the resistance values to get the total resistance (R, hr · ft^2 · °F/Btu), then take the reciprocal and multiply by the area of Zone B (0.60 ft^2) to get the area transmittance (UA, Btu/hr · °F).

Area Transmittance, Zone B	
Component	**Unit Resistance, R**
Outside air @ 15 mph	0.17
Hardboard siding, 1/2 in.	0.67
Extruded polystyrene, 1 in.	5.00
Cavity Insulation	11.00
Gypsum	0.45
Inside air	0.61
Total R =	18.0
UA = (1/18.0) * 0.6 =	0.033

6. Calculate R-value.

Sum the UA values for Zones A and B to get the area transmittance (UA, BTU · in/hr · °F) for the basic area:

UA = 0.033 + 0.033 = 0.066

Divide the basic area (ft^2) by the area transmittance to get the R-value (hr · ft^2 · °F/Btu):

R = 0.87/0.066 = 13.2

2.2 NAHB Research Center Chart Method

The NAHB Research Center developed a simplified chart, Figure 6, that can be used to determine the R-value directly It is based on finite-difference computer modeling and correlation with test data. The test data are within ±5% of values determined from the graph. Its use is illustrated below for the same wall construction as the preceding example.

From Figure 6, intersect the vertical line for a sheathing R-value of 5 with the sloping line for R-11 cavity insulation. Read the R-value of the wall from the left of the chart as 13. Compare the result with that obtained by the previous method, 13.2. In this example, the results are within 2%.

3. Suggested Insulation Levels to Meet Model Energy Code

Following enactment of the Federal Energy Policy Act in 1992, States have been directed to establish energy standards based on the Conference of American Building Code Officials (CABO) Model Energy Code (MEC). The MEC defines various approaches for compliance. In selecting the appropriate insulation system for the energy demand, the added cost of increasing levels of insulation must be weighted against the value of the energy savings. In general, insulation levels to meet the MEC will likely be more stringent than those dictated by past practice.

Energy demands are based on maps showing contours of the normal number of heating degree-days (HDD) per year, Figure 7. The HDD is based on a 65°F reference temperature; e.g. a temperature of 60°F for one day would represent 5 degree-days. To develop suggested levels of insulation to meet the MEC, trade-off calculations based on typical costs were made for energy demands from 4000 to 7000 degree-days, as indicated by the marked contours in Figure 7. The results are shown in the table on the following page.

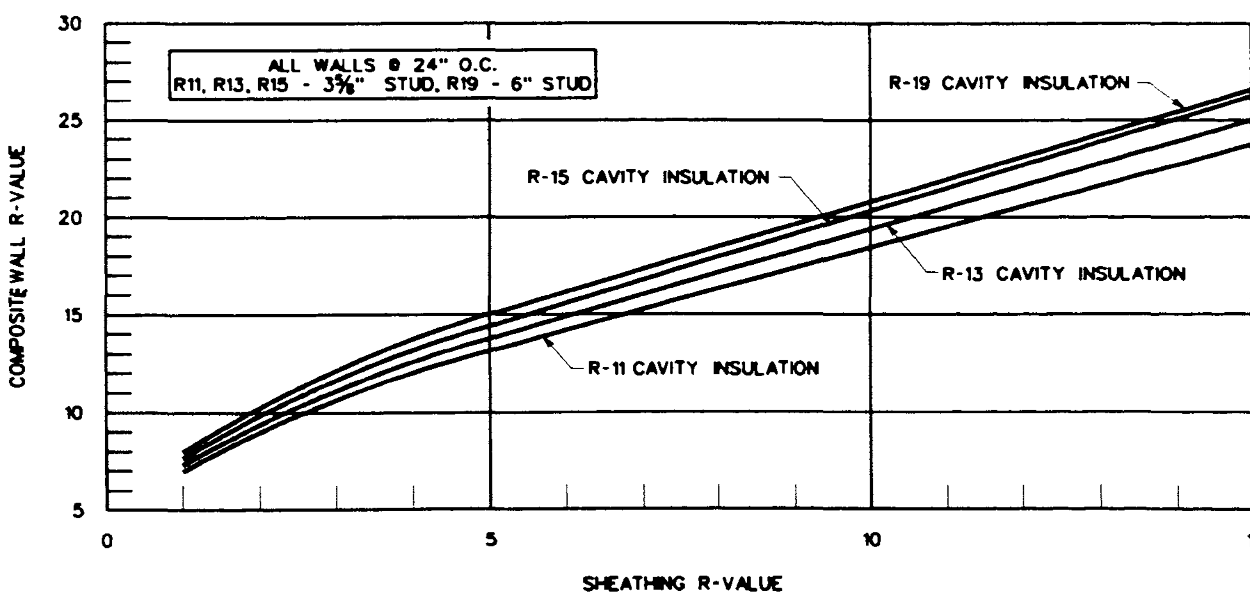


Figure 6. Simplified R-value chart for steel framed walls

Suggested Insulation Levels for Steel Framed Construction to Meet Model Energy Code				
Annual Degree-Day Demand	Cavity Insulation	Stud Depth, in.	Insulative Sheathing	Effective Wall R-Value
> 7000	R-19	6	2" XPS	R-20
7000 - 6000	R-19	6	1" XPS	R-15
7000 - 6000	R-11	3$^5/_8$	1$^1/_2$" XPS	R-15
6000 - 4000	R-13	3$^5/_8$	1" XPS	R-13.5
< 4000	—	3$^5/_8$	—	—

The table is based on a stud spacing of 24-in. Windows are assumed to comprise 12 percent of the total wall area and have an R value of 2.0. In addition to the insulative sheathing, an exterior sheathing of 0.50 in. hardboard siding or equivalent is also assumed. Interior sheathing is 0.50 in. gypsum wallboard with vapor barrier.

The table shows that, as the energy demand declines, the stud depth can be reduced. As shown for the 7000 to 6000 degree-day range, choices can be made between using a thicker insulative sheathing with a lower R-value cavity insulation, or a thinner insulative sheathing with a higher R-value cavity insulation. When the demand drops below 4000 degree-days, no insulation may be required to meet heating requirements.

A builder may required more or less insulation to meet the MEC, depending on the energy design approach used and other variables. Also, where the MEC is not mandated, required levels will likely be less than those shown in the above table.

4. Equivalent Insulation Systems

Sometimes it might be required to match the R-value of a particular wood framed construction system. For that purpose, the following table has been compiled showing equivalent insulation systems for steel and wood construction. As indicated, the addition of an exterior sheathing of extruded polystyrene (or a slightly thicker layer) is effective in matching thermal performance.

Equivalent Insulation Systems for Steel Framed Construction								
Wall R-Value	13		13.5		15		20	
Framing	Wood	Steel	Wood	Steel	Wood	Steel	Wood	Steel
ASHRAE Ref.	RW55		RW45B		RW13A		RW58	
Cavity Insulation R-Value	12	11	11	13	11	11	12	15
Ext. Sheathing	1/2" plywood + alum. siding	1" XPS	5/8" cedar + 4" brick	1" XPS	1" polyiso. + stucco	1$^1/_2$" XPS	1$^1/_2$" polyiso. + alum. siding	2" XPS

Notes:
Steel studs 3$^5/_8$" x 1$^5/_8$" @ 24".
Wood studs nom. 2" x 4" @ 16"
Interior sheathing is 1/2" gypsum wallboard for both.
Information on wood system is from ASHRAE Handbook.

5. Other Factors

Whether constructed of steel or other framing materials, the overall thermal performance of the completed structure depends on the quality of the construction job. Careful attention to insulation details, caulking around openings etc. will pay dividends. Steel framing members are inherently straight and true, making it easier to attain quality construction.

In addition to the present products, builders and others should be on the alert for new insulation products that hold promise for more efficient thermal construction. Such products currently under development by the insulation industry, should offer more construction options in the future.

Reference

E. Barbour and J. Goodrow, J. Kosney, J. E. Christian, "Thermal Performance of Steel-Framed Walls," NAHB Research Center, Inc., Upper Marlboro, MD., November 21, 1994.

Thermal Zone Map for Steel Framing

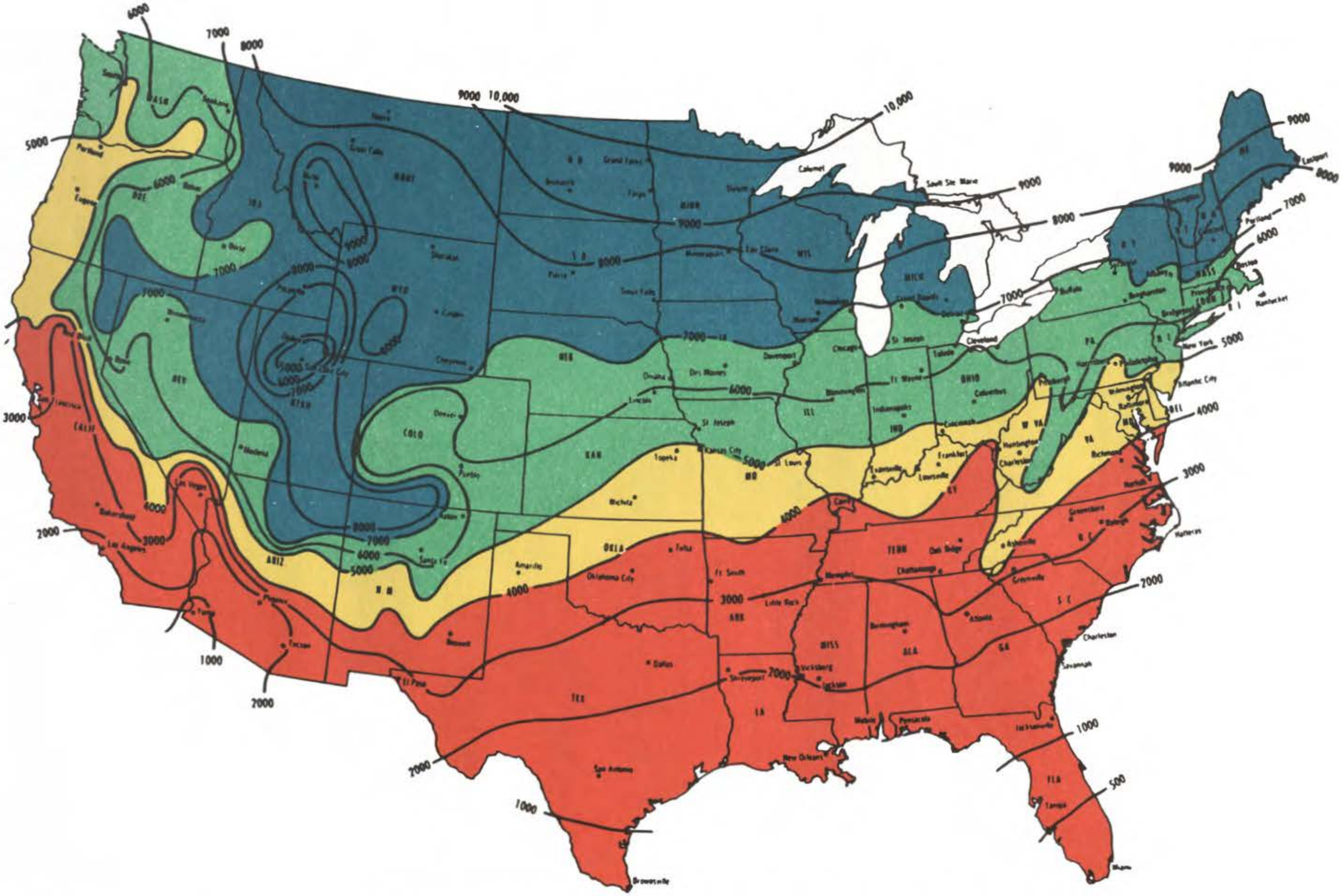


Figure 7. Normal number of degree-days per year. (Reproduced with permission from Handbook of Air Conditioning, Heating and Ventilating, *2nd ed., Industrial Press, Inc., New York, 1965.)*

CALCULATION NOTES

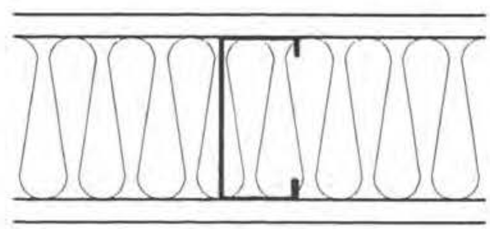
If you have questions, call 1-800-79-STEEL.

SYSTEM DESCRIPTION | **SKETCH AND DESIGN DATA**

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied to $1^5/_8 \times 3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

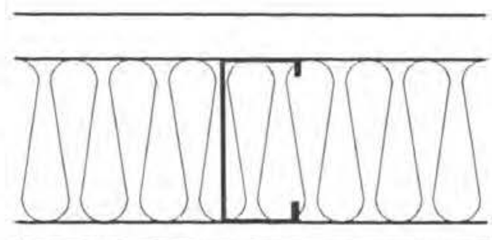


R-Value: 7.9
Test No.: A1

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to $1^5/_8 \times 3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

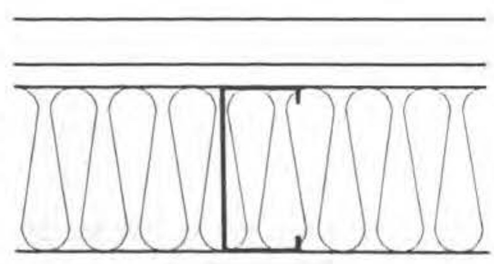


R-Value: 13.7
Test No.: A2

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, GYPSUM WALLBOARD, EXTRUDED POLYSTYRENE FOAM

Exterior Side: Base layer of 1/2 in. gypsum wallboard applied to $1^5/_8 \times 3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. **Face** layer of 1 in. extruded polystyrene foam applied to studs with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.



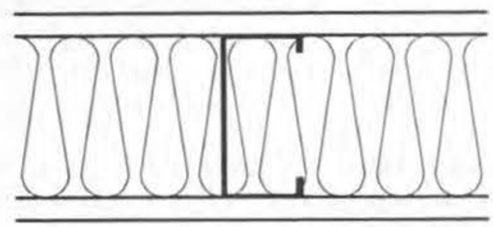
R-Value: 13.9
Test No.: A4

SYSTEM DESCRIPTION	SKETCH AND DESIGN DATA

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1/2 in. extruded polystyrene foam applied to $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

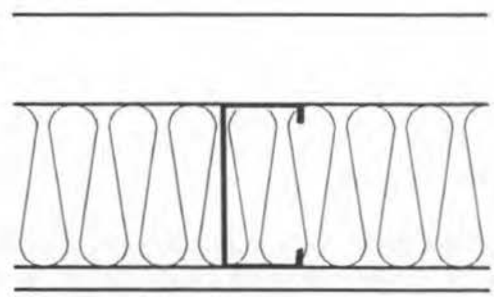


R-Value: 11.4
Test No.: A5

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 2 in. extruded polystyrene foam applied to $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

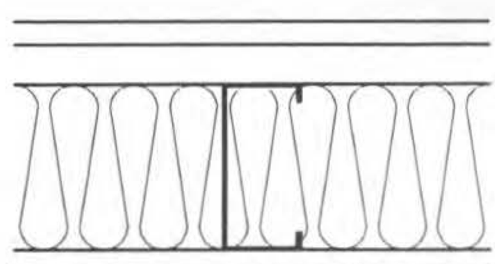


R-Value: 18.9
Test No.: A6

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, STEEL FURRING, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied to 7/8-in.-deep hat section steel furring strips with No. 6 bugle head screws, over $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.



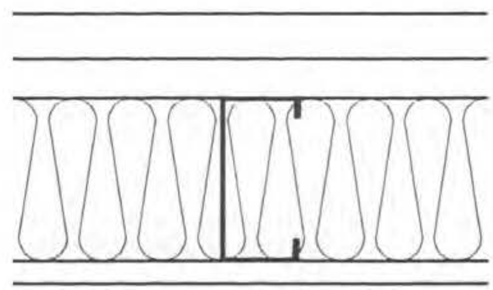
R-Value: 9.3
Test No.: A7

SYSTEM DESCRIPTION	SKETCH AND DESIGN DATA

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, STEEL FURRING, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to 7/8-in.-deep hat section steel furring strips with No. 6 bugle head screws with $1^1/_4$ in. dia. washers, over $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

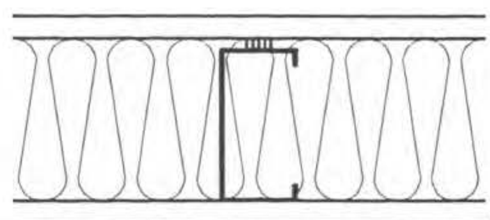


R-Value: 14.4
Test No.: A8

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, FOAM TAPE, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied over silicone foam tape, 3/4 in. wide by 5/16 in. thick, to $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

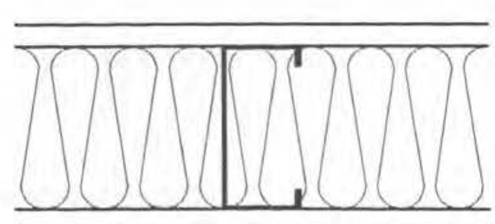


R-Value: 8.4
Test No.: A9

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied to $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 12 in. o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.



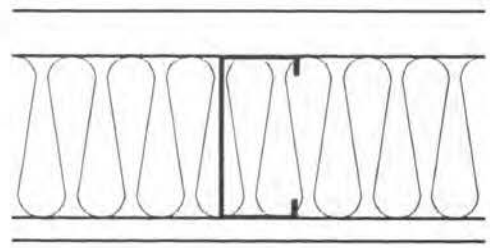
R-Value: 6.8
Test No.: B1

SYSTEM DESCRIPTION | **SKETCH AND DESIGN DATA**

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 12 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

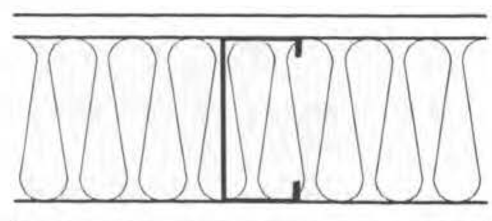


R-Value: 12.4
Test No.: B2

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1/2 in. plywood applied over silicone foam tape, 3/4 in. wide by 5/16 in. thick, to $1^5/_8$ x $3^5/_8$ x 0.033 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

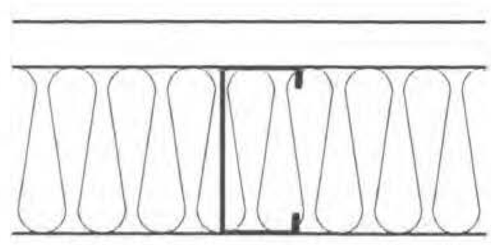


R-Value: 8.3
Test No.: C1

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, GYPSUM WALLBOARD, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to $1^5/_8$ x $3^5/_8$ x 0.033 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.



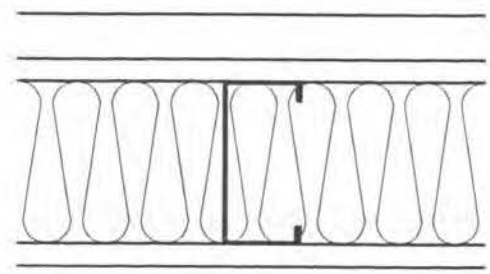
R-Value: 13.9
Test No.: C2

SYSTEM DESCRIPTION | **SKETCH AND DESIGN DATA**

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, PLYWOOD, EXTRUDED POLYSTYRENE FOAM

Exterior Side: Base layer of 1/2 in. plywood applied to $1^5/_8$ x $3^5/_8$ x 0.033 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. **Face** layer of 1 in. extruded polystyrene foam applied to studs with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

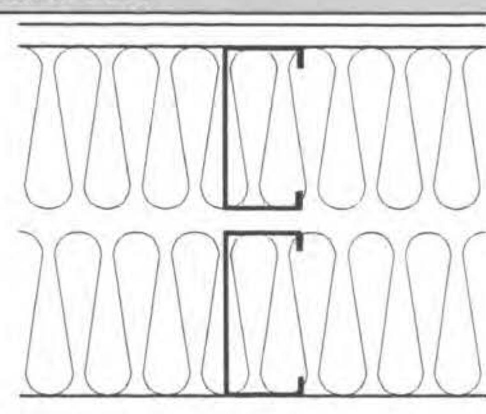


R-Value: 14.5
Test No.: C3

GYPSUM WALLBOARD, DOUBLE LAYER OF STEEL STUDS, GLASS FIBER INSULATION, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied to $1^5/_8$ x $3^5/_8$ x 0.033 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws; 7/8 in. air space; and a second layer of $1^5/_8$ x $3^5/_8$ x 0.033 in. steel C-section studs, spaced 24 in. o.c. The two layers of studs are held together by lengths of steel C-sections of same size, spaced at 32 in. o.c. vertically. Each layer of studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Two layers of full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

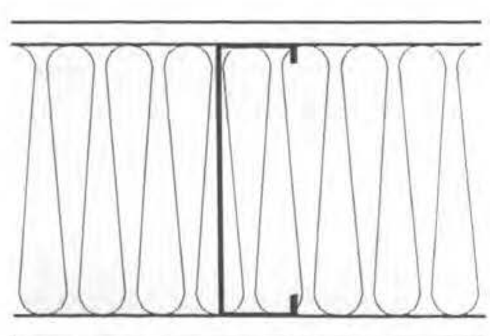


R-Value: 13.3
Test No.: C4

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied to $1^5/_8$ x 6 x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-19 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.



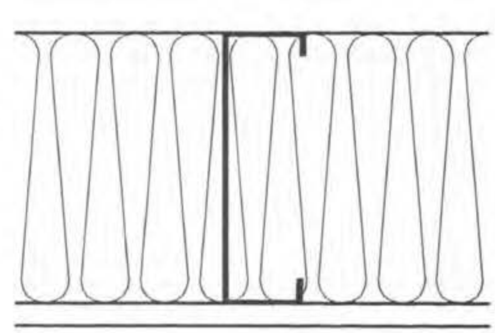
R-Value: 10.1
Test No.: D1

SYSTEM DESCRIPTION	SKETCH AND DESIGN DATA

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to $1^5/_8$ x 6 x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-19 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

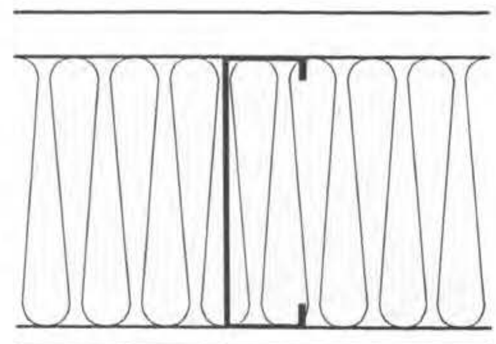


R-Value: 16.2
Test No.: D2

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYISOCYANURATE FOAM

Exterior Side: One layer of 1 in. aluminum-foil faced extruded polyisocyanurate foam applied to $1^5/_8$ x 6 x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-19 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

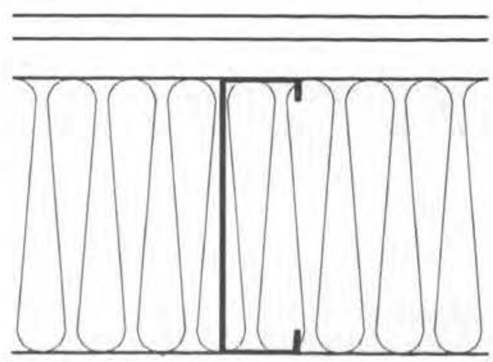


R-Value: 17.1
Test No.: D3

GYPSUM WALLBOARD, STEEL FURRING, GLASS FIBER INSULATION, STEEL FURRING, PLYWOOD

Exterior Side: One layer of 1/2 in. plywood applied to 7/8-in.-deep hat section steel furring strips with No. 6 bugle head screws, over $1^5/_8$ x 6 x 0.043 in. steel C-section studs, spaced 48 in. o.c. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-19 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to 7/8-in.-deep hat section steel furring strips with No. 6 bugle head screws, attached to studs.



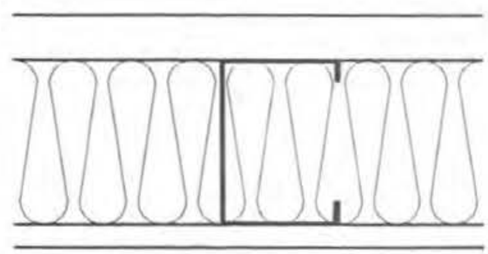
R-Value: 12.4
Test No.: D4

SYSTEM DESCRIPTION | **SKETCH AND DESIGN DATA**

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to $2^1/_2$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-11 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

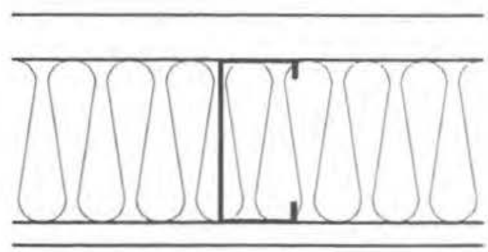


R-Value: 13.5
Test No.: E1

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM

Exterior Side: One layer of 1 in. extruded polystyrene foam applied to $1^5/_8$ x $3^5/_8$ x 0.043 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. Studs fit inside C-section tracks of same size, top and bottom, joined with No. 6, type S-12, 5/16 in. pan head screws. Full-width unfaced R-15 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.

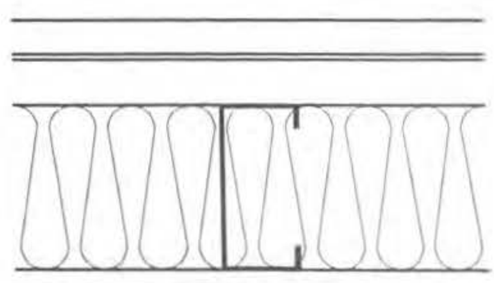


R-Value: 15.6
Test No.: F1

GYPSUM WALLBOARD, STEEL STUDS, GLASS FIBER INSULATION, EXTRUDED POLYSTYRENE FOAM, STUCCO

Exterior Side: Base layer of 1 in. extruded polystyrene foam applied to $1^5/_8$ x $3^5/_8$ x 0.033 in. steel C-section studs, spaced 24 in. o.c., with No. 6 bugle head screws with $1^1/_4$ in. dia. washers. **Face** layer of 3/4 in. stucco applied over wire mesh. (No tracks were used for this assembly.) Full-width unfaced R-13 glass fiber insulation batts fit in wall cavity and inside the studs.

Interior Side: One layer of 1/2 in. gypsum wallboard applied over 4 mil polyethylene vapor barrier to studs with No. 6 bugle head screws.



R-Value: 15.7
Test No.: F2

NOTES