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Sizing Air-Conditioning and Heating Equipment for Residential Buildings with ICF Walls

by Martha G. Van Geem, John Gajda, and Bruce Wilcox

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ABSTRACT

Insulating concrete forming systems (ICF) are used to build energy-efficient structural concrete walls. ICFs are panels, planks, or hollow blocks usually made of expanded polystyrene (EPS) or extruded expanded polystyrene (XPS) insulation. The ICFs are erected at the job site and filled with portland cement concrete to form walls. The walls uniquely combine the thermal mass of the concrete with the high thermal resistance of insulated sides to provide an energy efficient system in any climate.

This publication guides ICF users through *Manual J Residential Load Calculation,* a publication of the Air Conditioning Contractors of America. Manual J is the most widely used method of sizing HVAC equipment for residences. Manual J uses Heat Transfer Multipliers (HTMs) to calculate heating and cooling loads. The HTM for a wall is the amount of heat that flows through one square foot of wall at a given temperature difference.

This publication provides HTMs for heating and cooling for ICF walls so Manual J procedures can be used for these systems. For climates with medium and high daily temperature ranges as defined by Manual J, HTMs (cooling) for ICF walls are significantly less than those currently in Manual J for masonry walls. However, the design cooling load is dominated by the heat gain through windows rather than walls. Simplified worksheets are provided with step-by-step examples of Manual J cooling load calculations for homes with ICF walls.

This publication also provides more general guidelines or rules of thumb in response to current practice. Many air-conditioning systems in residences are sized using rules of thumb based on square feet of floor area. These methods are crude because they neglect building geometry and orientation; the insulating capabilities of the walls, windows, and roofs in the building envelope; and numerous other building features. Nevertheless, cooling factors for use with such rules of thumb are also provided in this publication. Recommended reductions in cooling loads for homes with ICF walls compared to frame walls range from 1 to 23% depending on the climate.

Typical HTM values for ICF walls for designing heating equipment are also provided. Manual J and standard industry practice make no allowance for mass effects when sizing heating systems.

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Sizing Air-Conditioning and Heating Equipment for Residential Buildings with ICF Walls

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1. ICF SYSTEMS

Insulating concrete forming systems (ICF) filled with concrete are used as walls in residences, including basements, up to three stories. ICFs are available from more than 20 manufacturers and their use in the United States and Canada is growing. The Portland Cement Association has helpful information on selecting and using ICFs. Compared to conventional frame construction, ICF walls are more durable, stronger, quieter, and more resistant to natural disasters.

The features of ICF systems vary between manufacturers, but fall into eight general categories.(1)** The systems are differentiated by the type of insulation unit, the shape of the cavity, and the method of connecting the two sides of insulation.

Units are generally divided into panels, planks, and blocks, as shown in Fig.1. Panels can be as large as 4 ft high by 8 ft wide. Planks are generally 8 ft wide and 8 to 12 inches high. Block systems have edges with teeth or tongue and groove so they interlock.

Three basic cavity shapes are flat, grid, or post-and-beam as shown in Fig. 2. Walls with flat panels have concrete of a uniform thickness. Thermal properties of these walls can be calculated. Grid or post-and-beam walls have concrete and insulation that varies in thickness. A grid system resembles a waffle or screen with interconnecting vertical and horizontal concrete sections. A "waffle" grid system has thin layers of concrete between the vertical and horizontal members. A "screen" grid system, shown in Fig. 3, has foam insulation between the vertical and horizontal member. A post-and-beam system has concrete sections spaced at greater distances than the grid system. Thermal properties of grid and post-and-beam walls are more complex to calculate than flat systems and thermal testing is recommended.

The third major difference between ICF systems is the type of connector between the inside and outside panel. Figure 4 shows panels with connectors of steel or plastic ties, or a foam insulation web. Plastic ties are less conductive than steel and allow for a more optimal use of the insulation. Systems with insulation ties resemble conventional concrete block, with the block material being insulation rather than concrete.

Although dimensions vary, the two insulation layers in ICF walls are each generally 2-in. thick and the concrete is 4- to 6-in. thick.

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**Numbers in parentheses refer to references.

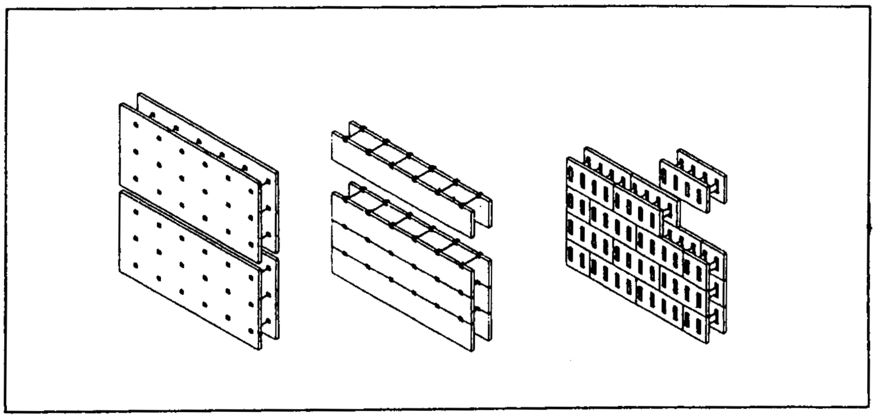


Fig. 1 Panel, Plank, and Block Systems

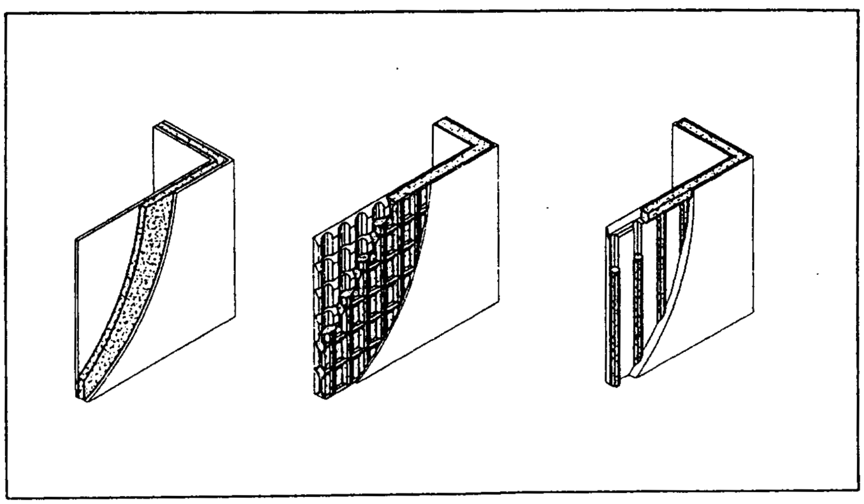


Fig. 2 Flat, Grid, and Post-and-Beam Systems

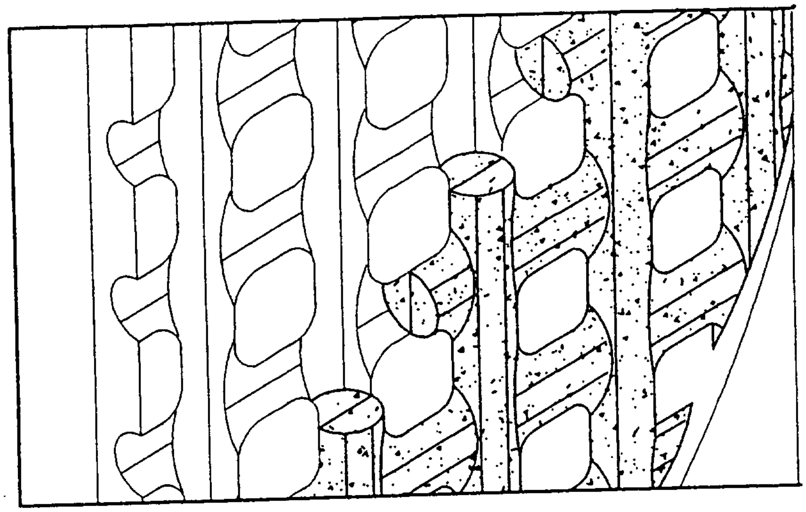


Fig. 3 Cutaway View of a "Screen" Grid System

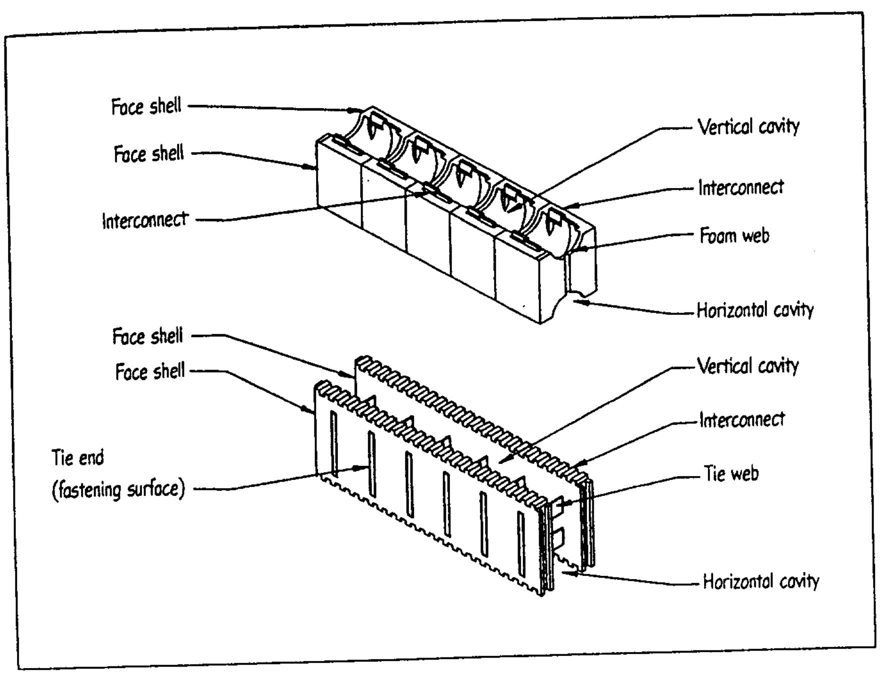


Fig. 4 Parts of ICF Units

2. SIZING AIR-CONDITIONING EQUIPMENT USING MANUAL J

This section guides ICF users through the cooling load portion of *Residential Load Calculation Manual J*,[2] a publication of the Air Conditioning Contractors of America. Manual J is the most widely used method of sizing HVAC equipment for residences. Manual J Sections IV, V, VI, and VII are used to size air-conditioning equipment of residences. "Section IV - Heat Gain of a Structure" outlines basic assumptions for designing air-conditioning equipment. "Section V - Heat Gain Calculations" provides step-by-step procedures for design. "Section VI - Example Problem: Heat Gain Calculations" is a detailed example. "Section VII - Basic Principles" describes the assumptions embedded in Manual J calculation procedures.

This section provides Heat Transfer Multipliers (HTMs) for cooling design for ICF walls, instructions for performing cooling load calculations, and examples.

HEAT TRANSFER MULTIPLIERS (HTMs) AND EQUIVALENT TEMPERATURE DIFFERENCES (ETDs) FOR ICF WALLS

Manual J[2] uses Heat Transfer Multipliers (HTMs) to calculate heating and cooling loads. The HTM for a wall is the amount of heat that flows through one square foot of wall at a given temperature difference. For cooling, the HTM is equal to the component thermal transmittance (U-factor) times the summer equivalent temperature difference (ETD).

$$\text{HTM (cooling)} = \text{ETD} \times \text{U} \qquad \text{(Eq. 1)}$$

where:

HTM = Heat transfer multiplier; heat flow through one sq ft of a wall at a given temperature difference, Btu/hr·ft^2

ETD = Equivalent temperature difference (summer), °F

U = Thermal transmittance of component, $\text{Btu/hr·ft}^2\text{·°F}$

Manual J, Figure 7-4 provides ETDs for two types of exterior walls, "frame and veneer on frame" and "masonry walls, 8-in. block or brick." ETDs for ICF walls have been calculated by Wilcox[3] and are presented in Table 1. The ETD and HTM are dependent on climate and, in particular, the design temperature difference and daily temperature range. Climate data are listed for the United States and Canadian locations in Table 1 of Manual J. The "Summer - 2½% design db" is the summer design temperature that is exceeded only 2-½% of the summer hours. The design temperature difference is this summer design temperature less the indoor thermostat set point for summer, recommended to be 75°F. For example, for Chicago, the design temperature difference is:

89°F (design temp.) - 75°F (summer set point) = 14°F.

The summer daily ranges are also listed in Table 1 of Manual J. Although actual values are listed, all that is needed is whether the climate is "L" for low, "M" for medium, or "H" for high. Using Table 1 of Manual J, the daily range for Chicago is medium (M).

Table 1 - Equivalent Temperature Differences (ETDs) for Exterior Walls

Design Temperature Difference, °F	10		15			20			25		30	35
Daily Temperature Range	L	M	L	M	H	L	M	H	M	H	H	H
ICF Wall	6.5	3.1	15.3	7.1	3.1	20.3	9.1	6.2	14.5	5.7	13.5	26.3
Masonry Walls, 8-in. block or brick	10.3	6.3	15.3	11.3	6.3	20.3	16.3	11.3	21.3	16.3	21.3	26.3
Frame and Veneer-on-frame Walls	17.6	13.6	22.6	18.6	13.6	27.6	23.6	18.6	28.6	23.6	28.6	33.6

Table 2 - Heat Transfer Multipliers (HTMs) for Cooling for ICF Walls (an addition to Table 4 of Manual J)

No. 14 - Insulated Concrete Form (ICF) Walls	10		15			20			25		30	35	U
Finished - Above Grade	L	M	L	M	H	L	M	H	M	H	H	H	
	HTM (Btuh per sq. ft.)												
I. ICF Wall with R-12 Insulation	0.5	0.2	1.1	0.5	0.2	1.5	0.7	0.5	1.1	0.4	1.0	1.9	.074
J. ICF Wall with R-15 Insulation	0.4	0.2	0.9	0.4	0.2	1.2	0.5	0.4	0.9	0.3	0.8	1.6	.060
K. ICF Wall with R-16 Insulation	0.4	0.2	0.9	0.4	0.2	1.2	0.5	0.4	0.8	0.3	0.8	1.5	.057
L. ICF Wall with R-17 Insulation	0.4	0.2	0.8	0.4	0.2	1.1	0.5	0.3	0.8	0.3	0.7	1.4	.054
M. ICF Wall with R-20 Insulation	0.3	0.1	0.7	0.3	0.1	0.9	0.4	0.3	0.7	0.3	0.6	1.2	.046
N. ICF Wall with R-22 Insulation	0.3	0.1	0.6	0.3	0.1	0.9	0.4	0.3	0.6	0.2	0.6	1.1	.042

Note: Values include interior and exterior finishes and are for flat panel systems with no metal ties. For systems with irregular shapes or metal form ties connecting the interior and exterior insulation layers, use U-factors from Appendix A or product manufacturer to calculate the HTM (HTM = ETD x U-factor).

Using the preceding Table 1 and rounding the design temperature difference from 14 to 15, the ETD for an ICF wall is 7.1°F. Note that the ETD for a frame wall in Chicago is 18.6°F and the ETD for a masonry block wall in Chicago is 11.3°F. Since the heat gain through a sq ft of wall in the summer (HTM) is the product of the ETD and the wall U-factor, the ICF wall allows less heat gain into the residence during design conditions than other wall types with the same U-factor.

A discussion of U-factors for ICF walls is provided in Appendix A.

The HTM for any wall is the ETD from Table 1 multiplied by the U-factor. Typical HTM values for ICF walls are presented in Table 2. The values for ICF walls in Table 2 are consistent with values in Table 4 of Manual J. Values for ICF walls in Table 2 are for flat panel systems with no metal ties. For systems with irregular shaped insulation or metal form ties connecting the interior and exterior insulation layers, use U-factors determined in accordance with Appendix A to calculate the HTM. All Manual J cooling HTMs include the effects of thermal mass and solar radiation (see footnote 5 to Manual J, Table 4.)

INSTRUCTIONS AND WORKSHEETS FOR COOLING LOAD CALCULATIONS

The cooling load for a residential building can be calculated using "Worksheet B1 - Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J," located in Appendix B. This worksheet includes 16 steps and incorporates procedures in Sections V and VI of Manual J. For ease of performing multiple calculations, the worksheet can be implemented in a spreadsheet. Note that the letters that appear in parentheses in the steps refer to Worksheet B1.

These procedures are for determining cooling loads of conventional houses with glass area approximately 10 to 25% of the floor area. Determining loads for solariums, atriums or liberal use of glass requires a more detailed calculation. The design does not incorporate unusual loads such as a large number of plants, a hot tub, or entertaining large groups of people.

Step 1 Design Conditions

Indoor design conditions are specified by the designer. Indoor design conditions of 75°F and 50 or 55% relative humidity are recommended in Manual J. Outdoor design conditions are from Table 1 of Manual J.

Step 2 Building Description

Information required to complete Step 2 is determined from architectural drawings or is specified in the design. The building area and perimeter are determined from the plan dimensions of the building. Forced ventilation into the conditioned space is outdoor air that is mechanically introduced into the conditioned space through heating and cooling equipment (such as air-to-air heat exchangers).

Step 3 Windows, Skylights, and Glass Doors

The window orientation and description are used to determine the window HTM from Tables 3A through 3F of Manual J. The number of panes of glass, type of glass, and shading are required. The total heat gain through windows (K) is the sum of the individual window areas multiplied by their HTM.

Step 4 Non-Glass Doors

The type and area of non-glass doors are used to determine the door HTM from Manual J, Table 4, Section Nos. 10 or 11. The total heat gain through non-glass doors (M) is the sum of the individual door areas multiplied by their HTM. The window portion of doors is included in Step 3 as windows.

Step 5 Above Grade Exterior Walls

The wall construction is used to determine the wall HTM from Table 2 of this report for ICF walls or Manual J, Table 4, Sections 12 and 14 for other exterior walls. Either the wall components or the wall U-factor can be used to determine the HTM. The total heat gain through walls (P) is the sum of the individual wall areas multiplied by their HTM.

Step 6 Partition Walls between Conditioned and Unconditioned Spaces

Partition walls between conditioned and unconditioned spaces are those that separate the spaces that are heated or cooled from those that are enclosed but not heated or cooled, such as garages or scuttle attics. The wall construction is used to determine the wall HTM from Manual J, Table 4, Section 13. The total heat gain through partition walls (Q) is the sum of the individual wall areas multiplied by their HTM.

Step 7 Ceilings Below Exterior or Unconditioned Spaces

The ceiling / roof construction is used to determine the ceiling HTM from Manual J, Table 4, Sections 16, 17, or 18. The total heat gain through the ceiling (R) is the ceiling area multiplied by its HTM.

Step 8 Floors Above Exterior or Unconditioned Spaces

The construction of floors separating conditioned space from the outdoors (exterior) or unconditioned spaces (unheated basements or crawl spaces) is used to determine the floor HTM from Manual J, Table 4, Sections 19 through 23. The total heat gain through the floor (S) is floor area multiplied by its HTM.

Step 9 Air Infiltration (Sensible)

The sensible heat gain due to infiltration in summer is calculated assuming the infiltration rate is known. An infiltration rate of 0.35 air changes per hour (ACH) is commonly assumed for tight houses, and is the recommended value for ICF homes. Although typical ICF walls are highly resistant to air infiltration, they make up less than 20% of the total area exposed to outdoors for a typical single-family detached house. Infiltration through windows, ceilings, and joints also contribute to the whole house infiltration. Infiltration rates determined from blower door tests[4] or tracer gas methods[5] may be used in lieu of 0.35 ACH.

The air infiltration rate in cubic ft per minute (cfm) (W) is equal to the infiltration rate multiplied by the volume of conditioned air. Note that this is the total volume of conditioned space above grade. If a conditioned basement is located so that one-half is above grade and one-half is below grade, only the above grade portion is included in the calculation.

The sensible cooling load due to infiltration (X) is determined from the air infiltration rate (W) and the design temperature difference (D).

Step 10 People and Appliances

The heat gain due to people is assumed to be 300 Btuh per person. The number of people is assumed to be twice the number of bedrooms. The heat gain due to kitchen and other household appliances is assumed to be 1200 Btuh.

Step 11 Partial Heat Gain

The partial heat gain is the heat gain from the building envelope, air infiltration, people, and appliances; and is the sum of the values calculated in Steps 3 through 11.

Step 12 Cooling Ducts in Unconditioned Spaces

Additional heat gain to the HVAC system occurs when cooling ducts are located in unconditioned spaces. To calculate this heat gain, estimate the percentage of ducts in unconditioned spaces, and use the appropriate duct gain multiplier from Manual J, Table 7B "Duct Gain Multipliers". The heat gain due to cooling ducts in unconditioned spaces (dd) is a function of the duct gain multiplier and the partial heat gain calculated in Step 11.

Step 13 Total Sensible Heat Gain

The total sensible heat gain is the partial heat gain calculated in Step 11 plus the heat gain due to ducts in unconditioned spaces calculated in Step 12.

Step 14 Sensible Equipment Sizing Load

The sensible ventilation load (ff) is the sensible heat gain associated with forced ventilation specified in Step 2. The total sensible load for the structure (gg) is the sum of the total sensible heat gain from Step 13 plus the sensible ventilation load.

If the cooling equipment is sized to limit the deviation from the indoor design temperature to 3°F or less and the outdoor design temperature is 95°F, the rating and temperature swing multiplier (RSM) is assumed to be 1.0. If not, use Manual J, Table 6 to determine the appropriate RSM. The sensible equipment sizing load (ii) is equal to the sensible load for the structure multiplied by the RSM.

Step 15 Latent Equipment Sizing

The latent ventilation load (kk) is the latent heat gain associated with forced ventilation specified in Step 2. The latent internal load (mm) is assumed to be 230 Btuh per person. The latent infiltration load (oo) is determined from the infiltration load previously determined in Step 9. The latent equipment sizing load is the sum of the three latent loads: ventilation, internal, and infiltration.

Step 16 Summary

The total cooling load is the sum of the sensible equipment sizing load (ii) determined in Step 14 and the latent equipment sizing load (pp) determined in Step 15.

A separate worksheet is provided for use with Worksheet B1 when windows are shaded by overhangs. Instructions are self-explanatory for "Worksheet B2 - Simplified Worksheet to Determine Heat Gain Through Partially Shaded Windows of a Residential Building using Manual J," located in Appendix B.

COOLING LOAD CALCULATION EXAMPLES

Example No. 1 — Ranch House:

Problem: Determine the cooling load for a 3-bedroom, 30 by 50 ft (1500 sq ft) ranch house constructed of 10-ft high ICF walls with R16 insulation. The house, located in Chicago, has slab-on-grade construction with R10 perimeter insulation, a wood frame attic with R-38 insulation above the ceiling, a light-colored roof, and two solid wood exterior doors with metal storm doors. There are 50 sq ft of windows on each cardinal orientation (N, S, E, and W), each with double-pane low-e glass and no interior blinds. The windows facing south are 5 ft high, and shaded by a 2 ft overhang located 2 ft above the top of the window. The ducts are located above the insulation in the attic and have R6 insulation. Makeup air of 70 cubic ft per minute is mechanically supplied to the home.

Solution: Table 3 is completed Worksheets B1 and B2 with values for Example 1. The sensible equipment sizing load (ii) is 16,600 Btuh and the latent equipment sizing load (pp) is 4700 Btuh, for a total cooling load of 21,300 Btuh. This example shows that the heat gain through windows, 51% of the total sensible load, dominates the cooling design load. The heat gain through the ICF wall is 3% of the total sensible load.

TABLE 3 - Cooling Load Example No. 1

WORKSHEET B1 – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

Building Name: Example I - Ranch House   Prepared by: John Gajda

Building City & State: Chicago, IL   Date: August 1, 1997

STEP 1 - DESIGN CONDITIONS

Indoor Design Condition: 75 °F (**A**) *{75°F RECOMMENDED}*

55 % RH *{50 OR 55% RH RECOMMENDED}*

Outdoor Design Condition: 89 °F dry bulb (**B**)

74 °F wet bulb

31 Grains Difference at RH (**C**)

M Daily Range (L, M, H)

{FROM TABLE 1 OF MANUAL J}

Allowable Temperature Variation 3 °F *{3°F OR 4.5°F RECOMMENDED}*

Design Temperature Difference (**D = B - A**) 15 °F *{CAN ROUND UP 3°F OR DOWN 1°F}*

(Actually 14, but round to 15)

STEP 2 - BUILDING DESCRIPTION

Building Description 30 ft by 50 ft Ranch - 1 Story, Slab-on-Grade

Building Perimeter 160 ft   Building Area, in plan (**E**) 1500 ft^2

Ceiling Height (**F**) 10 ft

Total Above-Grade Exterior Window, Wall and Door Area (**G**) 1600 ft^2

Forced Ventilation into Conditioned Space (**H**) 70 cfm

Roof Color Light (Light or Dark)

STEP 3: WINDOWS, SKYLIGHTS, AND GLASS DOORS *{USE TABLES 3A THROUGH 3F OF MANUAL J}*

Orientation	Description	Area, ft^2	HTM	Area x HTM
East	Double Pane, Low-e, No drapes or blinds, and no overhang	50	63	3150
West		50	63	3150
North		50	18	900
South	See worksheet B2	50	—	1193
	Total (**J**)	200	Total (**K**)	8393

Note: If windows are partially shaded by overhangs, use calculations in Worksheet B2

WORKSHEET B1 (cont) – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

STEP 4: NON-GLASS DOORS *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
Solid Wood with	10F	22.5	6	135
Metal Storm	10F	22.5	6	135
	Total (**L**)	45	Total (**M**)	270

STEP 5: ABOVE GRADE EXTERIOR WALLS *{USE TABLE 2 OF THIS REPORT OR TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
R-16 ICF Wall	14K	1355	0.4	542
	Total (**N**)	1355	Total (**P**)	542

Note: (**N**) 1355 must be equal to (**G - J - L**) 1600 - 45 - 200 = 1355 (YES)

STEP 6: PARTITION WALLS BETWEEN CONDITIONED AND UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Partition Wall Area	0	Total (**Q**)	0

STEP 7: CEILINGS BELOW EXTERIOR OR UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
R-38 under a vented attic and a Light Roof	16I4	1500	0.8	1200
	Ceiling Area	1500	Total (**R**)	1200

WORKSHEET B1 (cont) – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

STEP 8: FLOORS ABOVE EXTERIOR OR UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
Slab-on-Grade	21 - 23	1500	0	0
	Floor Area	1500	Total (S)	0

STEP 9: AIR INFILTRATION (SENSIBLE)

Total Floor Area of Conditioned Space (**T = E * *No. Stories***) 1500 ft^2

Summer Air Changes per Hour (**U**) 0.35 AC/hr *{0.35 AIR CHANGES RECOMMENDED}*

Total <u>Above Grade</u> Volume of Conditioned Space (**V = F * T**) 15,000 ft^3

Air Infiltration (**W = 0.0167 * U * V**) 87.7 cfm

Summer Infiltration (**X = 1.1 * D * W**) 1447 Btuh

STEP 10: PEOPLE AND APPLIANCES

Building Occupants (**Y**) 6 *{TYPICALLY TWICE THE NUMBER OF BEDROOMS}*

Heat Load (**Z = Y * 300 + 1200**) 3000 Btuh

STEP 11: PARTIAL HEAT GAIN

Partial Heat Gain (**aa = K + M + P + Q + R + S + X + Z**) 14,852 Btuh

STEP 12: COOLING DUCTS IN UNCONDITIONED SPACES

Are Cooling Ducts located in Unconditioned Spaces (Yes or No)? YES

If <u>**YES**</u> then:

Estimate Percentage of Ducts in Unconditioned Spaces (**bb**) 100 % (All Ducts in Attic)

Duct Gain Multiplier (**cc**) 0.10 *{USE TABLE 7B OF MANUAL J}*

Duct Gain (**dd = bb / 100 * aa * cc**) 1485 Btuh

WORKSHEET B1 (cont) – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

STEP 13: TOTAL SENSIBLE HEAT GAIN

Total Sensible Heat Gain (**ee = aa + dd**) 16,337 Btuh

STEP 14: SENSIBLE EQUIPMENT SIZING LOAD

Sensible Ventilation Load (**ff = 1.1 * D * H**) 1155 Btuh

Total Sensible Load for Structure (**gg = ee + ff**) 17,492 Btuh

Rating and Temperature Swing Multiplier (**hh**) 0.95 RSM *{USE TABLE 6 OF MANUAL J}*

Sensible Equipment Sizing Load (**ii = gg * hh**) 16,617 Btuh

STEP 15: LATENT EQUIPMENT SIZING LOAD

Latent Ventilation Load (**kk = 0.68 * C * H**) 1476 Btuh

Latent Internal Loads (**mm = 230 * Y**) 1380 Btuh

Latent Infiltration Load (**oo = 0.68 * C * W**) 1849 Btuh

Latent Equipment Sizing Load (**pp = kk + mm + oo**) 4705 Btuh

STEP 16: SUMMARY

Sensible Cooling (**ii**) 16,617 Btuh

Latent Cooling (**pp**) 4705 Btuh

Total Cooling Load (**ii + pp**) 21,322 Btuh

WORKSHEET B2 – Simplified Worksheet to Determine Heat Gain Through Partially Shaded Windows of a Residential Building using Manual J

Building Name: Example 1 - Ranch House   Prepared by: John Gajda

Building City & State: Chicago, IL   Date: August 1, 1997

STEP 1 - DESIGN CONDITIONS

Indoor Design Condition: 75 °F (**A**)   *{75°F RECOMMENDED}*

Outdoor Design Condition: 89 °F dry bulb (**B**)
M Daily Range (L, M, H)

Design Temperature Difference (**C = B - A**) 15 °F *{CAN ROUND UP 3°F OR DOWN 1°F}*

(Actually 14, but round to 15)

STEP 2 - SHADING MULTIPLIERS

Degrees North Latitute of Building 42   *{USE TABLE 1 OF MANUAL J}*

Shade Line Multipliers *{USE TABLE 8 OF MANUAL J}*:

East and West ($\mathbf{D_1}$) Not applicable

Southeast and Southwest ($\mathbf{D_2}$) Not applicable

South ($\mathbf{D_3}$) 2.38   (extrapolated between 2.6 and 2.05)

STEP 3 - DESCRIPTIONS OF OVERHANGS AND PARTIALLY SHADED WINDOWS

	Window				
Window Description	**No. 1**	**No. 2**	**No. 3**	**No. 4**	**No. 5**
Glass Type	Clear				
No. Panes	Double				
Glass Coating	Low-e				
Direction Faces	South				
Window width (**E**), in.	120				
Window Height (**F**), in.	60				
Heat Load of Window (if Shading is not Present) (**G**)	31				
Heat Load of Identical North Facing Window (**H**)	18				

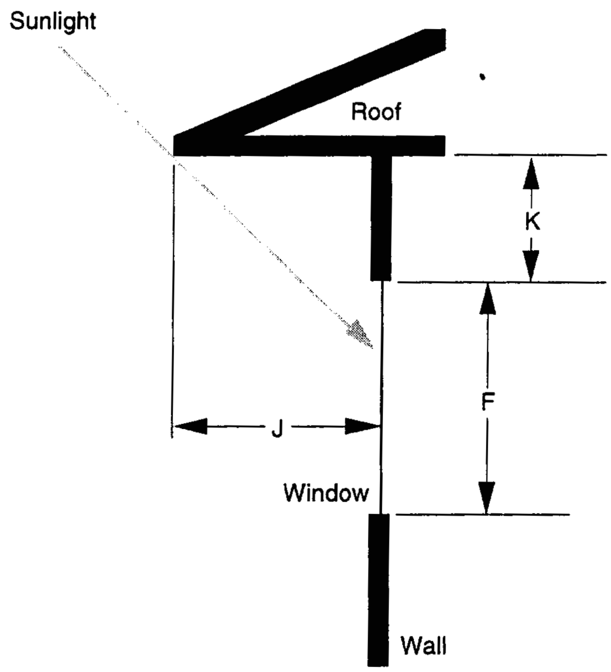
NOTE: Window assumed to be 10 ft wide by 5 ft tall (50 sq ft) for ease of calculation

Notes 1. It is recommended that values from Manual J - Table 3A are used.
2. Windows facing Northeast, North, and Northwest never receive direct sunlight and therefore are not shaded (no calculation is needed).

WORKSHEET B2 (cont) – Simplified Worksheet to Determine Heat Gain Through Partially Shaded Windows of a Residential Building using Manual J

STEP 4 - DESCRIPTIONS OF OVERHANGS ABOVE PARTIALLY SHADED WINDOWS

	Window				
Overhang Description	**No. 1**	**No. 2**	**No. 3**	**No. 4**	**No. 5**
Overhang Distance (**J**), in.	24				
Window to Overhang (**K**), in.	24				



STEP 5 - HEAT GAIN FROM PARTIALLY SHADED WINDOWS

	Window				
	No. 1	**No. 2**	**No. 3**	**No. 4**	**No. 5**
Shading Distance (**M = D * J**)	57				
Shaded Height (**P = M - K**)	33				
Unshaded Height (**Q = F - P**)	27				
Shaded Area (**S = E * P / 144**)	27.5				
Unshaded Area (**T = E * Q / 144**)	27.5				
Total Heat Gain (**S*H + G*T**)	1193				

Example No. 2 — Custom House:

Problem: Determine the cooling load for a 5-bedroom, two-story house measuring 25 by 60 ft in plan and constructed of 10-ft high ICF walls with R16 insulation. The house, located in Dallas, has a basement with one-half the height located below grade, a cathedral ceiling (45° pitch roof) with R-30 insulation, a dark-colored roof, and three solid wood exterior doors. There are 200 sq ft of windows on each cardinal orientation (N, S, E, and W), each with double-pane low-e tinted glass and interior blinds. A north-facing skylight at 45° inclination also has double-pane low-e tinted glass. The HVAC ducts are located within the conditioned space. Makeup air of 130 cubic ft per minute is mechanically supplied to the home.

Solution: Table 4 is a completed Worksheet B1 with values for Example 2. The sensible equipment sizing load (ii) is 39,500 Btuh and the latent equipment sizing load (pp) is 8710 Btuh, for a total cooling load of 48,200 Btuh. This example shows that the heat gain through windows, 46% of the total sensible load, dominates the cooling design load. The heat gain through the ICF wall is 3% of the total sensible load.

TABLE 4 - Cooling Load Example No. 2

WORKSHEET B1 – Simplified Worksheet to Determine the Cooling Load of a Residential Building Manual J

Building Name: Example 2 - Custom House   Prepared by: John Gajda

Building City & State: Dallas, TX   Date: August 2, 1997

STEP 1 - DESIGN CONDITIONS

Indoor Design Condition: 75 °F (**A**) *{75°F RECOMMENDED}*
50 % RH *{50 OR 55% RH RECOMMENDED}*

Outdoor Design Condition: 100 °F dry bulb (**B**)
75 °F wet bulb *{FROM TABLE 1 OF MANUAL J}*
27 Grains Difference at RH (**C**)
M Daily Range (L, M, H)

Allowable Temperature Variation 3 °F *{3°F OR 4.5°F RECOMMENDED}*

Design Temperature Difference (**D = B - A**) 25 °F *{CAN ROUND UP 3°F OR DOWN 1°F}*

STEP 2 - BUILDING DESCRIPTION

Building Description 25 ft by 60 ft Custom Home - 2 Stories with Finished Basement

Building Perimeter 170 ft   Building Area, in plan (**E**) 1500 ft^2

Ceiling Height (**F**) 10 ft

Total Above-Grade Exterior Window, Wall and Door Area (**G**) 4250 ft^2

1700 ft^2 - 1st floor
1700 ft^2 - 2nd floor
850 ft^2 - Above-grade Basement

Forced Ventilation into Conditioned Space (**H**) 130 cfm

Roof Color Dark (Light or Dark)

STEP 3: WINDOWS, SKYLIGHTS, AND GLASS DOORS *{USE TABLES 3A THROUGH 3F OF MANUAL J}*

Orientation	Description	Area, ft^2	HTM	Area x HTM
North	Double Pane, Low-e, tinted glass with blinds, and no overhang	200	9	1800
South		200	13	2600
West		200	24	4800
East		200	24	4800
Skylight	North, 45° Inclination	50	80	4000
	Total (**J**)	850	Total (**K**)	18,000

Note: If windows are partially shaded by overhangs, use calculations in Worksheet B2

WORKSHEET B1 (cont) – Simplified Worksheet to the Cooling Load of a Residential Building using Manual J

STEP 4: NON-GLASS DOORS *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
Solid Wood	10D	22.5	13.2	297
Solid Wood	10D	22.5	13.2	297
Solid Wood	10D	22.5	13.2	297
	Total (L)	67.5	Total (M)	891

STEP 5: ABOVE GRADE EXTERIOR WALLS *{USE TABLE 2 OF THIS REPORT OR TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
R-16 ICF Wall	14K	3332.5	0.4	1333
	Total (N)	3332.5	Total (P)	1333

Note: (N) 3332.5 must be equal to (G - J - L) 4250 - 67.5 - 850 = 3332.5 (YES)
For simplicity, skylights are treated as windows

STEP 6: PARTITION WALLS BETWEEN CONDITIONED AND UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Partition Wall Area	0	Total (Q)	0

STEP 7: CEILINGS BELOW EXTERIOR OR UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
R-30 under a Vented Attic with a Dark Roof	18F	2121	1.7	3606
	Ceiling Area	2121	Total (R)	3606

Since ceiling is vaulted, it follows the roof line (45° inclination). Assuming no dormers and a conventional gable roof, the roof area is 2 * (60 * (1/2 * 25 / Cos (45°))) or 2121 sq ft.

WORKSHEET B1 (cont) – Simplified Worksheet to the Cooling Load of a Residential Building using Manual J

STEP 8: FLOORS ABOVE EXTERIOR OR UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
Basement Slab	21 - 23	1500	0	0
	Floor Area	1500	Total (S)	0

STEP 9: AIR INFILTRATION (SENSIBLE)

Total Floor Area of Conditioned Space (**T = E * *No. Stories***) 4500 ft^2

Summer Air Changes per Hour (**U**) 0.35 AC/hr *{0.35 AIR CHANGES RECOMMENDED}*

Total Above Grade Volume of Conditioned Space (**V = F * T**) 37,500 ft^3

Normally 45,000, but only half of basement is above grade, therefore = 2.5 * 10 * 1500

Air Infiltration (**W = 0.0167 * U * V**) 219 cfm

Summer Infiltration (**X = 1.1 * D * W**) 6028 Btuh

STEP 10: PEOPLE AND APPLIANCES

Building Occupants (**Y**) 10 *{TYPICALLY TWICE THE NUMBER OF BEDROOMS}*

Heat Load (**Z = Y * 300 + 1200**) 4200 Btuh

STEP 11: PARTIAL HEAT GAIN

Partial Heat Gain (**aa = K + M + P + Q + R + S + X + Z**) 34,058 Btuh

STEP 12: COOLING DUCTS IN UNCONDITIONED SPACES

Are Cooling Ducts located in Unconditioned Spaces (Yes or No)? NO

If **YES** then:

Estimate Percentage of Ducts in Unconditioned Spaces (**bb**) 0 % (No Ducts in Attic)

Duct Gain Multiplier (**cc**) - *{USE TABLE 7B OF MANUAL J}*

Duct Gain (**dd = bb / 100 * aa * cc**) 0 Btuh

WORKSHEET B1 (cont) – Simplified Worksheet to the Cooling Load of a Residential Building using Manual J

STEP 13: TOTAL SENSIBLE HEAT GAIN

Total Sensible Heat Gain (**ee = aa + dd**) 34,058 Btuh

STEP 14: SENSIBLE EQUIPMENT SIZING LOAD

Sensible Ventilation Load (**ff = 1.1 * D * H**) 3575 Btuh

Total Sensible Load for Structure (**gg = ee + ff**) 37,633 Btuh

Rating and Temperature Swing Multiplier (**hh**) 1.05 RSM *{USE TABLE 6 OF MANUAL J}*

Sensible Equipment Sizing Load (**ii = gg * hh**) 39,515 Btuh

STEP 15: LATENT EQUIPMENT SIZING LOAD

Latent Ventilation Load (**kk = 0.68 * C * H**) 2387 Btuh

Latent Internal Loads (**mm = 230 * Y**) 2300 Btuh

Latent Infiltration Load (**oo = 0.68 * C * W**) 4021 Btuh

Latent Equipment Sizing Load (**pp = kk + mm + oo**) 8708 Btuh

STEP 16: SUMMARY

Sensible Cooling (**ii**) 39,515 Btuh

Latent Cooling (**pp**) 8708 Btuh

Total Cooling Load (**ii + pp**) 48,223 Btuh

3. SIZING AIR-CONDITIONING EQUIPMENT USING A SIMPLIFIED METHOD

Many air-conditioning systems in residences are sized using rules of thumb based on square feet of floor area. These methods are crude because they neglect building geometry and orientation; the insulating capabilities of the walls, windows, and roofs in the building envelope; and numerous other building features. Nevertheless, cooling factors for use with such rules of thumb are provided in Table 5 in the row labeled "recommended." These values, determined by Wilcox[3], represent the percentage of peak cooling load for a prototypical house with ICF walls and R16 insulation (U-factor of 0.55) compared to the same house with R13 frame walls. Values are dependent on the design temperature difference and daily temperature range previously defined in Section 2.

For each design temperature difference and daily temperature range, Table 5 also lists the results of Wilcox's analysis[3] including average, maximum, minimum, standard deviation, and number of locations analyzed for each column. The recommended value is the lesser of (1) the maximum or (2) the average plus two standard deviations. Alternatively, results for each city analyzed are presented in Appendix A of Ref. 3 under "cooling size multiplier." Values are based on a 1540 sq ft single story ranch with specific features[3] and may not be applicable to other houses.

Table 5 - Crude Cooling Size Multipliers for ICF Walls

Design Temperature Difference, °F	**≤5**			**10**			**15**		**20**		**25**		**30**
Daily Temperature Range	**L**	**M**	**H**	**L**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**H**
Recommended	**93%**	**87%**	**77%**	**99%**	**96%**	**83%**	**97%**	**90%**	**92%**	**88%**	**90%**	**88%**	**90%**
Average	74%	78%	75%	93%	88%	79%	91%	84%	90%	84%	90%	87%	90%
Maximum	93%	87%	77%	99%	96%	85%	98%	90%	92%	88%	90%	88%	90%
Minimum	47%	27%	71%	85%	76%	74%	84%	79%	88%	80%	89%	85%	90%
Standard Deviation	20%	14%	3%	3%	4%	2%	3%	3%	1%	3%	0%	2%	—
Number of Locations Analyzed	6	19	3	15	65	22	49	20	12	5	2	2	1

4. GUIDELINES FOR COOLING DESIGN

When selecting air-conditioning equipment (other than heat pumps) oversizing should be kept to a minimum[2]. Oversizing causes the equipment to cycle on infrequently, which can lead to high indoor relative humidities. This potentially leads to comfort problems, condensation, and the possibility of mold and mildew.

Adequate exhaust ventilation to the outdoors should be provided in the kitchens and bathrooms to remove excess moisture generated in the home. In relatively tight construction such as ICF homes, bathroom fans controlled by relative humidity sensors have been found to be beneficial.

Air-conditioning ducts should be located within the conditioned space wherever feasible to reduce duct losses.

5. SIZING HEATING EQUIPMENT USING MANUAL J

Manual J sections I, II, III, and VII are used to size heating equipment of residences. "Section I - Heat Loss of a Structure" outlines basic assumptions for designing air-conditioning equipment. "Section II - Heat Loss Calculations" provides step-by-step procedures for design. "Section III - Example Problem: Heat Loss Calculations" is a detailed example. "Section VII - Basic Principles" describes the assumptions embedded in Manual J calculation procedures.

HEAT TRANSFER MULTIPLIERS (HTMS) FOR ICF WALLS

Manual J also uses Heat Transfer Multipliers (HTMs) to calculate heating loads. The HTM for a wall is the amount of heat that flows through one square foot of wall at a given temperature difference. For heating, the HTM is equal to the component thermal transmittance (U-factor) times the winter temperature difference (WTD).

$$\text{HTM (cooling)} = \text{WTD} \times \text{U} \qquad \text{(Eq. 2)}$$

where:

HTM = Heat transfer multiplier: heat flow through one sq ft of a wall at a given temperature difference, $\text{Btu/hr}\cdot\text{ft}^2$

WTD = Winter temperature difference, °F

U = Thermal transmittance of component, $\text{Btu/hr}\cdot\text{ft}^2\cdot°\text{F}$

The HTM is dependent on climate and, in particular, the winter design temperature difference. This climate data is listed for the United States and Canadian locations in Table 1 of Manual J. The "Winter- 97½% design db" is the winter design temperature that is exceeded 97-½% of winter hours. The design temperature difference is this winter design temperature less the indoor thermostat set point for winter. For example, for Chicago, the design temperature difference is:

70°F (winter set point) - (-4°) F (design temp.) = 74°F.

The HTM for an ICF wall is the winter temperature difference times the U-factor. Typical HTM values for ICF walls are presented in Table 6. These values are consistent with values in Table 2 of Manual J. Values are for flat panel systems with no metal ties. For systems with irregular shaped insulation or metal form ties connecting the interior and exterior insulation layers, use U-factors determined in accordance with Appendix A to calculate the HTM. All Manual J cooling HTMs include the effects of thermal mass a to calculate the HTM. Manual J heating HTMs do not include the effects of thermal mass and solar radiation.

Table 6 - Heat Transfer Multipliers (HTM's) for Heating for ICF Walls (an Addition to Table 2 of Manual J)

No. 14 - Insulated Concrete Form (ICF) Walls	Winter Temperature Difference																
Finished - Above Grade	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**U**
	HTM (Btuh per sq. ft.)																
I. ICF Wall with R-12 Insulation	1.5	1.8	2.2	2.6	3.0	3.3	3.7	4.1	4.4	4.8	5.2	5.5	5.9	6.3	6.6	7.0	0.074
J. ICF Wall with R-15 Insulation	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7	0.060
K. ICF Wall with R-16 Insulation	1.1	1.4	1.7	2.0	2.3	2.6	2.8	3.1	3.4	3.7	4.0	4.3	4.6	4.8	5.1	5.4	0.057
L. ICF Wall with R-17 Insulation	1.1	1.3	1.6	1.9	2.2	2.4	2.7	3.0	3.2	3.5	3.8	4.0	4.3	4.6	4.9	5.1	0.054
M. ICF Wall with R-20 Insulation	0.9	1.2	1.4	1.6	1.9	2.1	2.3	2.6	2.8	3.0	3.2	3.5	3.7	3.9	4.2	4.4	0.046
N. ICF Wall with R-22 Insulation	0.8	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.8	3.0	3.2	3.4	3.6	3.8	4.0	0.042

Note: Values include interior and exterior finishes and are for flat panel systems with no metal ties. For systems with irregular shapes or metal form ties connecting the interior and exterior insulation layers, use U-factors from Appendix A or product manufacturer to calculate the HTM (HTM = WTD x U-factor).

HEATING SYSTEM DESIGN

The purpose of heating equipment sizing is to ensure that the heating system is large enough to maintain comfort under design but not necessarily worst case weather conditions. Manual J and standard industry practice make no allowance for mass effects when sizing heating systems. Heating system loads are generally calculated assuming the indoor and outdoor temperature are constant at their design values and there are no solar or internal gains. Under these conditions there are no mass effects. For sizing purposes the calculated loads are often increased by a safety margin to account for morning warm-up where mass effects result in larger rather than smaller equipment size.

Procedures and an example for sizing heating equipment are in Chapters II and III of Manual J. The heating analysis is simpler than cooling, and is covered adequately in Manual J.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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APPENDIX A —THERMAL PROPERTIES OF ICF WALLS

The energy savings of construction materials is generally marketed using thermal resistance (R-value), but Manual J uses thermal transmittance (U-factor) to determine HTDs.

DEFINITION OF THERMAL RESISTANCE (R-VALUE)

Thermal resistance (R-value) is defined as the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions. This is equal to the temperature difference divided by the steady-state heat flow through a unit area of a material or construction. For a homogeneous material, thermal resistance is equal to a material's thickness divided by thermal conductivity.

For a wall constructed of layers of material perpendicular to the heat flow, such as an ICF panel wall with a uniform cavity thickness and no metal ties, the total thermal resistance (R_T) of the wall is the sum of the resistances of the layers that make up the wall as shown in Fig. A1. This includes the insulation, concrete, inside finish such as gypsum wallboard, outside finish such as vinyl siding, and interior and exterior air films. An air film resistance is the thermal resistance between the material surface at the surface of the wall and the air.

DEFINITION OF THERMAL TRANSMITTANCE (U-FACTOR)

Thermal transmittance (U-factor) is defined as the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by a unit temperature difference between steady-state environments on each side[6]. Thermal transmittance is the reciprocal of the total thermal resistance. Higher thermal resistance (R-value) and lower thermal transmittance (U-factor) provide more energy efficiency.

INSULATION R-VALUES

The thermal resistance of the insulation layers in ICF walls depends on their thickness, material, and density. Thermal conductivities and thermal resistances per inch of insulations used in ICF walls are provided in Table A1. Expanded polystyrene (EPS) is molded beads fused together. Extruded expanded polystyrene (XPS) has a smooth skin surface. Thermal conductivity (k) is defined as the time rate of steady-state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area. This property is for a unit thickness of material.

XPS has a higher thermal resistance per inch than EPS, but is more expensive. Some distributors use EPS, some use XPS, and some offer both. Polyurethane foam is also used.

EXAMPLE CALCULATION OF R_T AND U FOR ICF WALLS WITH UNIFORM INSULATION THICKNESSES

For a wall constructed of layers of material perpendicular to the heat flow, the total thermal resistance (R_T) of the wall is the sum of the resistances of the layers that make up the wall. This method is applicable to ICF walls with a uniform cavity thickness and no metal ties, such as flat panel, flat plank, and flat block walls. Thermal transmittance (U) is the inverse of the total thermal resistance (R_T).

$$R_T = R_o + R_1 + R_2 + R_3 + R_4 + R_5 + R_i$$

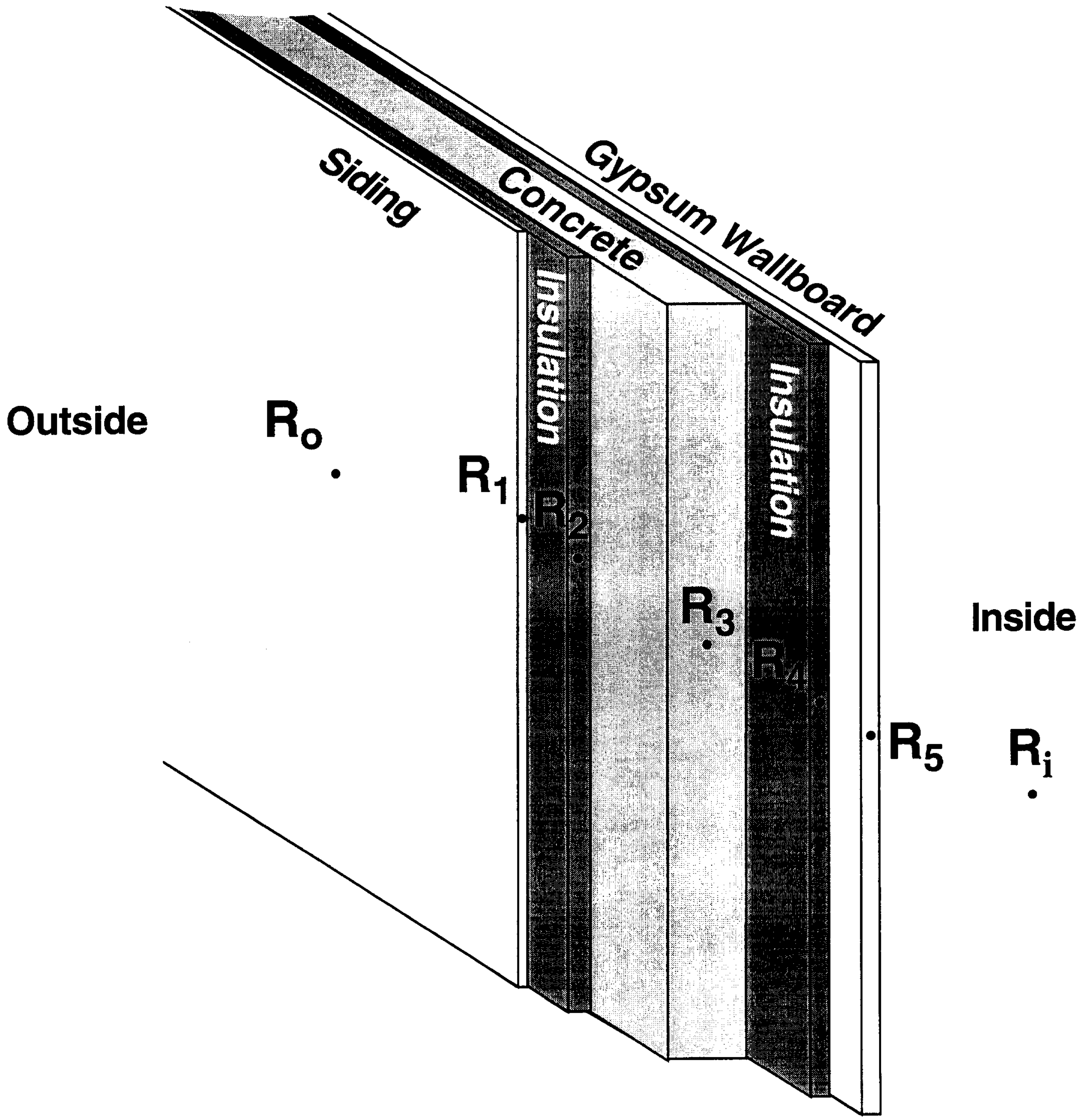


Fig. A1 Example of Total Thermal Resistance (R_T)

TABLE A1 - THERMAL PROPERTIES OF BOARD INSULATION[5]

Insulation	Density, lb/ft3	Thermal Conductivity k, $\frac{\text{Btu·in}}{\text{hr·ft}^2\text{·°F}}$	Thermal Resistance R Per Inch Thickness ($1/k$), $\frac{\text{hr·ft}^2\text{·°F}}{\text{Btu·in}}$
Expanded polystyrene, molded beads (EPS)	1.00	0.26	3.85
	1.25	0.25	4.00
	1.50	0.24	4.17
	1.75	0.24	4.17
	2.00	0.23	4.35
Expanded polystyrene, extruded (smooth skin surface) (XPS)	1.8-3.5	0.20	5.00
Polyurethane foam	1.5-2.5	0.16-0.18	6.25-5.56

Example No. A1:

Problem: Determine the total thermal resistance (R_T) of a flat plank ICF wall with 2 in. of expanded polystyrene insulation (EPS) on each side and a 6-in. concrete core. The inside surface is ½-in. gypsum wallboard and the outside surface is wood siding. The EPS has a 1 pcf density.

Solution: Using Table A1, the thermal conductivity of the 1 pcf EPS is 0.26 Btu·in./hr·ft^2·°F. The thermal conductivity of normal weight concrete is assumed to be 16 Btu·in./hr·ft^2·°F. The resistance of a material is the thickness divided by the thermal conductivity. Calculations are shown in Table A2. The total thermal resistance (R_T) is 17.7 hr·ft^2·°F/Btu and the thermal transmittance (U) is 0.057 Btu/hr·ft^2·°F.

R_T AND U VALUES FOR NONUNIFORM INSULATION THICKNESSES

Detailed complex calculations are required for systems with nonuniform insulation thicknesses or systems with metal ties that penetrate the insulation layers. In these cases, the higher conducting concrete and steel cause thermal bridges that increase heat loss. Area weighting the U-factors of materials in the wall cross-sections (the parallel path method) underestimates the effects of these thermal bridges in most cases. To accurately determine the R-value or U-factor of the wall cross section, one of the following must be used:

(1.) Two or three dimensional finite difference or finite element computer model
(2.) Isothermal planes calculation method
(3.) Zone calculation method
(4.) Hot box test (ASTM C 236[7] or C 976[8]) on a typical ICF wall section

TABLE A2 - EXAMPLE NO. A1, CALCULATION OF R_T AND U FOR ICF WALL WITH UNIFORM INSULATION THICKNESS

Component	R Thermal Resistance, hr·ft^2·°F/Btu
1. Outside air film	0.17*
2. Wood siding	0.60
3. 2-in. expanded polystyrene (EPS) insulation, 1 pcf density (2/0.26)	7.69
4. 6-in. normal weight concrete (6/16)	0.38
5. 2-in. expanded polystyrene (EPS) insulation	7.69
6. 1/2-in. gypsum wallboard	0.45
7. Inside air film	0.68*
R_T (sum)	17.7
U** ($1/R_T$)	0.057

*Ref. 5, Chapter 24.

**Units for thermal transmittance are Btu/hr·ft^2·°F.

The hot box test method is preferred since many of the ICF systems have curved shapes in multiple dimensions that make analysis complex and results subject to assumptions. The hot box test report should include wall dimensions and insulation properties such as type, density and thermal conductivity provided by the manufacturer. It is recommended the test be performed by a reputable laboratory familiar with hot box testing of mass walls.

The isothermal planes calculation method is generally applicable to complex insulation shapes. The zone calculation method is generally applicable to systems with metal ties. These methods are explained in Refs. 5, 9, and 10. It is recommended the calculations be performed by a qualified engineer familiar with energy analysis.

APPENDIX B — DESIGN WORKSHEETS

WORKSHEET B1 – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

Building Name: ____________________________ Prepared by: ______________________

Building City & State: ____________________________ Date: ______________________

STEP 1 - DESIGN CONDITIONS

Indoor Design Condition: _______°F (**A**) *{75°F RECOMMENDED}*
_______% RH *{50 OR 55% RH RECOMMENDED}*

Outdoor Design Condition: ________ °F dry bulb (**B**)
________ °F wet bulb
________ Grains Difference at RH (**C**)
________ Daily Range (L, M, H)
{FROM TABLE 1 OF MANUAL J}

Allowable Temperature Variation _______°F *{3°F OR 4.5°F RECOMMENDED}*

Design Temperature Difference (**D = B - A**) _____°F *{CAN ROUND UP 3°F OR DOWN 1°F}*

STEP 2 - BUILDING DESCRIPTION

Building Description ____

Building Perimeter _________ ft Building Area, in plan (**E**) ____________ ft²

Ceiling Height (**F**) ______ ft

Total Above-Grade Exterior Window, Wall and Door Area (**G**)__________ ft²

Forced Ventilation into Conditioned Space (**H**) __________ cfm

Roof Color __________ (Light or Dark)

STEP 3: WINDOWS, SKYLIGHTS, AND GLASS DOORS *{USE TABLES 3A THROUGH 3F OF MANUAL J}*

Orientation	Description	Area, ft²	HTM	Area x HTM
	Total (**J**)		Total (**K**)	

Note: If windows are partially shaded by overhangs, use calculations in Worksheet B2

WORKSHEET B1 (cont) – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

STEP 4: NON-GLASS DOORS *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Total **(L)**		Total **(M)**	

STEP 5: ABOVE GRADE EXTERIOR WALLS *{USE TABLE 2 OF THIS REPORT OR TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Total **(N)**		Total **(P)**	

Note: **(N)** __________ must be equal to **(G - J - L)** __________.

STEP 6: PARTITION WALLS BETWEEN CONDITIONED AND UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Partition Wall Area		Total **(Q)**	

STEP 7: CEILINGS BELOW EXTERIOR OR UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Ceiling Area		Total **(R)**	

WORKSHEET B1 (cont) – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

STEP 8: FLOORS ABOVE EXTERIOR OR UNCONDITIONED SPACES *{USE TABLE 4 OF MANUAL J}*

Description	Construction No.	Area, ft^2	HTM	Area x HTM
	Floor Area		Total (S)	

STEP 9: AIR INFILTRATION (SENSIBLE)

Total Floor Area of Conditioned Space (**T = E * *No. Stories***)___________ ft^2

Summer Air Changes per Hour (**U**)_________ AC/hr *{0.35 AIR CHANGES RECOMMENDED}*

Total <u>Above Grade</u> Volume of Conditioned Space (**V = F * T**) ____________ ft^3

Air Infiltration (**W = 0.0167 * U * V**) ______ cfm

Summer Infiltration (**X = 1.1 * D * W**) ___________ Btuh

STEP 10: PEOPLE AND APPLIANCES

Building Occupants (**Y**) ________ *{TYPICALLY TWICE THE NUMBER OF BEDROOMS}*

Heat Load (**Z = Y * 300 + 1200**) ___________ Btuh

STEP 11: PARTIAL HEAT GAIN

Partial Heat Gain (**aa = K + M + P + Q + R + S + X + Z**) ____________ Btuh

STEP 12: COOLING DUCTS IN UNCONDITIONED SPACES

Are Cooling Ducts located in Unconditioned Spaces (Yes or No)? __________

If <u>YES</u> then:

Estimate Percentage of Ducts in Unconditioned Spaces (**bb**) _______ %

Duct Gain Multiplier (**cc**) _________________ *{USE TABLE 7B OF MANUAL J}*

Duct Gain (**dd = bb / 100 * aa * cc**) ___________ Btuh

WORKSHEET B1 (cont) – Simplified Worksheet to Determine the Cooling Load of a Residential Building using Manual J

STEP 13: TOTAL SENSIBLE HEAT GAIN

Total Sensible Heat Gain (**ee = aa + dd**) ____________ Btuh

STEP 14: SENSIBLE EQUIPMENT SIZING LOAD

Sensible Ventilation Load (**ff = 1.1 * H * D**) ____________ Btuh

Total Sensible Load for Structure (**gg = ee + ff**) __________ Btuh

Rating and Temperature Swing Multiplier (**hh**) _________ RSM *(USE TABLE 6 OF MANUAL J)*

Sensible Equipment Sizing Load (**ii = gg * hh**) __________ Btuh

STEP 15: LATENT EQUIPMENT SIZING LOAD

Latent Ventilation Load (**kk = 0.68 * C * H**) ____________ Btuh

Latent Internal Loads (**mm = 230 * Y**) __________ Btuh

Latent Infiltration Load (**oo = 0.68 * C * W**) _________ Btuh

Latent Equipment Sizing Load (**pp = kk + mm + oo**) __________ Btuh

STEP 16: SUMMARY

Sensible Cooling (**ii**) _____________ Btuh

Latent Cooling (**pp**) _______________ Btuh

Total Cooling Load (**ii + pp**) _______________ Btuh

WORKSHEET B2 – Simplified Worksheet to Determine Heat Gain Through Partially Shaded Windows of a Residential Building using Manual J

Building Name: ______________________ Prepared by: ____________________

Building City & State: ______________________ Date: ____________________

STEP 1 - DESIGN CONDITIONS

Indoor Design Condition: _______°F **(A)** *{75°F RECOMMENDED}*

Outdoor Design Condition: ________ °F dry bulb **(B)**
________ Daily Range (L, M, H)

Design Temperature Difference (**C = B - A**) _____°F *{CAN ROUND UP 3°F OR DOWN 1°F}*

STEP 2 - SHADING MULTIPLIERS

Degrees North Latitute of Building __________ {USE TABLE 1 OF MANUAL J}

Shade Line Multipliers {USE TABLE 8 OF MANUAL J} :

East and West (**D_1**) ________

Southeast and Southwest (**D_2**) _________

South (**D_3**) ________

STEP 3 - DESCRIPTIONS OF OVERHANGS AND PARTIALLY SHADED WINDOWS

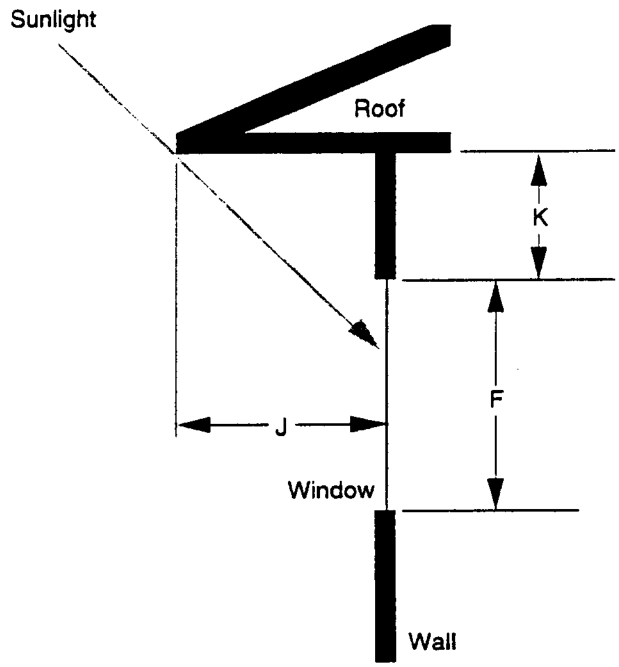
	Window				
Window Description	**No. 1**	**No. 2**	**No. 3**	**No. 4**	**No. 5**
Glass Type					
No. Panes					
Glass Coating					
Direction Faces					
Window width (**E**), in.					
Window Height (**F**), in.					
Heat Load of Window (if Shading is not Present) (**G**)					
Heat Load of Identical North Facing Window (**H**)					

Notes 1. It is recommended that values from Manual J - Table 3A are used.
2. Windows facing Northeast, North, and Northwest never receive direct sunlight and therefore are not shaded (no calculation is needed).

WORKSHEET B2 (cont) – Simplified Worksheet to Determine Heat Gain Through Partially Shaded Windows of a Residential Building using Manual J

STEP 4 - DESCRIPTIONS OF OVERHANGS ABOVE PARTIALLY SHADED WINDOWS

	Window				
Overhang Description	**No. 1**	**No. 2**	**No. 3**	**No. 4**	**No. 5**
Overhang Distance (**J**), in.					
Window to Overhang (**K**), in.					



STEP 5 - HEAT GAIN FROM PARTIALLY SHADED WINDOWS

	Window				
	No. 1	**No. 2**	**No. 3**	**No. 4**	**No. 5**
Shading Distance (**M = D * J**)					
Shaded Height (**P = M - K**)					
Unshaded Height (**Q = F - P**)					
Shaded Area (**S = E * P / 144**)					
Unshaded Area (**T = E * Q / 144**)					
Total Heat Gain (**S*H + G*T**)					