

A Guide to Manual J (7th and 8th Edition)

For more than 40 years, Manual J has been the industry's leading reference tool for performing residential load calculations. With over 30 years of experience teaching Manual J, we have observed that most students only need an orderly explanation of the load calculation process. This guide puts it all together in a smooth flowing, easy to understand booklet. This guide does not replace Manual J, as you will need the reference material in Manual J to accurately perform a load calculation. This manual is designed to be short on words and simple on math. Let's get started.

THE FOLLOWING INFORMATION IS FOR MANUAL J8 USERS (8TH EDITION)

Manual J8 was developed to provide two methods of calculating residential loads: **average load procedure** and **peak load procedure**.

The average load procedure is used to size the equipment used for homes with Adequate Exposure Diversity*. If the home will utilize zoning, the zone loads must be calculated using the peak load procedure.

***Adequate Exposure Diversity (AED)** - A home has AED if it is typical with about the same amount of fenestration (glass) facing all directions.

If the home does not have adequate exposure diversity, the peak load procedure must be used. It may be necessary to perform a number of calculations based on time of day or time of year, and then select the load that covers the worst case scenario.

A home does not have AED if it has a disproportional amount of glass facing any one direction.

An example of a home without AED would be one with an unusually large amount of glass facing south. Because the average load procedure is based on midsummer data, the equipment might be undersized in October when the sun gets lower and begins radiating through the large amount of south facing glass.

This course will teach you the Average Load Procedure, as it will be the most prevalent method you will be using in the field.

What is a load calculation?

All structures either *lose* heat in the winter time or *gain* heat in the summer time. This heat loss or heat gain is caused by the fact that the transfer of heat, even in a super insulated house, cannot be completely stopped.

If we know how much heat is being transferred through its walls, ceilings, floors, windows and doors, ducts and through infiltration (air leakage) on an hourly basis, then we could calculate the precise size heater or air conditioner the house would need to maintain a comfortable temperature. This calculation is called a *load calculation*. The load is measured in *BTUH's*

Why do a load calculation?

The obvious reason is to prevent installing a system that is too small to do the job. However, if this were the only reason, why wouldn't we just put a 5-ton air conditioner and a 140,000 BTUH furnace in a 1200 sq. ft. house and never worry about it again? The real reason for a load calculation is to size the equipment in order to assure comfort, economy, and good indoor air quality.

When heating, it is important to size the system as close to the heat loss calculation as possible to prevent (1) drafts, (2) hot and cold spots, and (3) short cycling of equipment. When a furnace is grossly oversized, the unit will constantly shut off and on. It may satisfy the thermostat but leave other parts of the home either over or under heated; thus leaving the occupants uncomfortable. A correctly sized unit runs longer, resulting in a better distribution of air and reduced short cycling. Short cycling also leads to higher energy costs. Each time a furnace fires up it has to heat up the heat exchange before the indoor fan comes on. This heat is wasted up the chimney. Short cycling (short on-off periods) increases the amount of heat wasted up the chimney. In addition, if the occupant is cold in the area he is sitting in (a cold spot), he will turn up the thermostat, which wastes fuel as other areas are over heated.

Sizing rules for *heating* (ACCA):

- **Fossil fuel furnaces** - Do not exceed 100% load calculation (may be twice the size required).
- **Electric resistance heat** - Do not exceed 10% of load calculation.
- **Heat pumps (used for heating and cooling)** - Do not exceed 25% of cooling load.
- **Heat pumps (used for heating only)** - Do not exceed 15% of heating load.
- **Auxiliary heat (electric resistance)** – Install only enough KW to make up for the heat pump's deficit. If more heat is desired, the additional heat must be controlled to remain off during normal heat pump operation.

Sizing an air conditioner correctly is even more important than sizing heat. Aside from causing hot and cold spots, over sizing an air conditioner can result in causing high humidity and the problems associated with it. When an air conditioner runs, it is not only cooling, it is dehumidifying. An oversized air conditioner will cool the house, but will not run long enough to dehumidify. High relative humidity can have two detrimental effects: (1) higher energy bills because higher humidity requires lower thermostat settings to remain comfortable, and (2) promote mold, mildew, moisture, and possibly health related problems. *NOTE: Even a correctly sized air conditioner is oversized most of the time. For example, a load calculation may call for a three-ton unit at 95-degree outdoor temperature, however, 97% of the time it is less than 95 degrees outdoors. A practical solution is to slightly undersize the unit, but talk this over with the owner.*

Sizing rules for *air conditioners* (ACCA):

- **Air conditioner** - May be sized up to 115% of calculation.
- **Heat pump** - May be sized up to 125% of calculation if needed to supply extra heating capacity.

A few basics before getting started

We're almost ready to do a load calculation. Before we get started, there are a few thermodynamic terms we need to discuss.

1st law of thermodynamics

Energy can neither be created nor destroyed, but can be converted from one form to another with some amount of heat given off during the conversion. For example, when we burn gasoline in our car we convert chemical energy (gasoline) to mechanical energy and heat energy. With a gasoline engine being about 35% efficient, 65 % of the energy in a gallon of gas is wasted as heat. A furnace converts fuel to heat with amazing efficiency (99% heat, 1% light). We cannot make a furnace more than 100% efficient; otherwise we would be creating energy. When we talk about a furnace being 80% efficient when heating a home, we are referring to the percentage of heat (80%) that goes into the home versus the percentage of heat that goes up the chimney (20%).

2nd law of thermodynamics

Heat goes from a warm place to a cold place. **Heat does not rise. Hot air rises.** The reason for stating this law is because many people are under the impression that heat rises; therefore, we only need to insulate ceilings. If that were true we'd only insulate the bottom of a refrigerator or top water heater. Heat travels in all directions—through walls, floors and ceilings—at the same rate.

How structures lose or gain heat

Heat is transferred by conduction, radiation or convection

Conduction - When heat is transferred through walls, floors, ceilings, doors and glass it passes from the cold surface to the warm surface by *conduction*. Similar to how a spoon handle gets warm after being place in a hot beverage.

Radiation - When heat is transferred form its source to an object without heating the medium in between. it is said to be *radiant heat*. An infrared heater is a source and the body is the object. The heater radiates its heat to the body but does not heat the air between the two.

Convection- When fluids (air is a fluid) of different temperatures mix they assume the weighted average temperature. An air handler produces forced convection. an electric baseboard produces natural convection and open windows or cracks produce infiltration, another source of convection.

BTU

The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Burning a match produces about 1 BTU.

BTUH

The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit in one hour's time.

SPECIFIC HEAT

The amount of heat required to raise the temperature of one pound of any substance compared to that of water. Water has a specific heat of 1.00 while the specific heat of rock is .20 and the specific heat of ice is .50. Therefore, it takes five times more heat to raise the temperature of water compared to rock and two times compared to ice. A Specific Heat Table of common substances can be found in *ASHRAE's Handbook of Fundamentals* (see Sensible Heat definition).

SENSIBLE HEAT

Heat we can measure with a thermometer. When we heat water from 70 degrees to 90 degrees we can see the thermometer rise. To determine the amount of sensible heat (BTUs) that is required to raise the temperature of a substance, use the following formula.

$$\text{BTU (sensible)} = \text{lbs.} \times \text{temp diff.} \times \text{specific heat}$$

Raise temp of 10 lbs. water 15 degrees	Raise temp of 10 lbs. rock 15 degrees
10 lbs. x 15 degrees TD x 1.00 = 150 BTU	10 lbs. x 15 degrees TD x .20 = 30 BTU

figure 1

Note: compared to rock, it takes five times more heat (BTU) to raise the temperature of the water.

Design temperature and design temperature difference (TD)

Table 1A
Outdoor Design Conditions for the United States

Location	Elevation Feet	Latitude Degrees North	Winter	Summer					Daily Range (DR)	
			Heating 99% Dry Bulb	Cooling 1% Dry Bulb	Coincident Wet Bulb	Design Grains 55% RH	Design Grains 50% RH	Design Grains 45% RH		
Alabama										
Alexander City	686	33	22	93	76	39	46	52	M	
Anniston AP	612	33	24	93	76	39	46	52	M	
Auburn	776	32	22	93	76	39	46	52	M	
Birmingham AP	644	33	23	92	75	34	41	47	M	
Decatur	592	34	16	93	74	27	34	40	M	
Dothan AP	401	31	32	93	76	39	46	52	M	
Florence AP	581	34	21	94	75	31	38	44	M	

figure 2

When you design a heating or air conditioning system you need to know how cold or hot it is likely to get in your area (this is the **outdoor design temperature**) and what temperature you'd like to maintain inside (this is the **indoor design temperature**). Table 1A in manual J (figure 2) will provide you with the outdoor conditions for major cities in the United States. For example, using Table 1A, look up Birmingham, AL. Under the heading *Heating 99% Dry Bulb* it indicates 23 degrees is the outdoor winter design temperature and under *Cooling 1% Dry Bulb*, 92 degrees is the outdoor summer design temperature.

NOTE 1: If you feel the temperatures in manual J are not true representations of your situation, use other data or experience, but do not go overboard. (Use Manual J figures when testing.)

NOTE 2: If you are heating or cooling an area that is adjacent to or surrounded by another area that is at a different temperature than outside, use the surrounding temperature as your outside design temperature. An example would be an office in the center of a 50 degree warehouse. Use 50 degrees for the outdoor temperature.

The inside design temperature should always be:

- 70 degrees F for winter*
- 75 degrees for summer*

*unless otherwise specified

The **design temperature difference (DTD)** is simply the difference between the indoor and outdoor design temperatures.

Example: What is the winter design temperature difference for Birmingham?

Answer: 70F - 23F = 47 DTD

Latent heat

The heat required to change the *state* of a substance is called *latent heat*. It cannot be measured with a thermometer. For example, if we

heat one pound of water ten degrees, it would take 10 BTUs, according to our definition of *sensible heat*. However, when we change the state of the water from liquid to vapor (steam), we are not changing the temperature, only the state. It also takes energy or BTUs to change the state. This is called *latent heat* or *latent heat of vaporization*, to be specific. It takes 970 BTUs to change the state of one pound of water from liquid to vapor or vapor to liquid at 212F, Therefore, the latent heat of vaporization of water at 212F is 970/lb.

When an air conditioner removes moisture from the air, it is converting (changing the state) water vapor to liquid, which flows down the drain line and out of the house. If you were to catch this water in a bucket and determined that 1.5 gals per hour were being produced by the air conditioner, you could calculate the amount of latent heat necessary to remove the moisture. Below is the formula.

$$\text{BTUH} = \text{latent heat} \times \text{weight}$$

Water weighs 8.33 lbs./gal.

$$8.33 \text{ lbs./gal.} \times 1.5 \text{ gals} = 12.5 \text{ lbs.}$$

$$1054 \text{ BTUs/lb.} \times 12.5 \text{ lbs.} = 13,175 \text{ BTUs (latent heat)}$$

Note: If you are paying attention, you'll notice a latent heat figure of 1054 btuh/lb is used in lieu of 970 btuh/lb. This is because the latent heat of vaporization changes somewhat as the vapor temperature changes. The temperature of the vapor at the cooling coil is about 40F as opposed to boiling water at 212F.

When calculating heat gain (air conditioning), two loads are figured. One is sensible heat and the other is latent heat. When selecting an air conditioner, it must have the capacity to satisfy both loads. Example: if the total calculated load comes to 28,344 BTUH, you might be tempted to install a 2 1/2 ton unit (30,000 BTUH). However, you must first check the manufacture's specs to see that both the sensible and latent loads will be covered. If the calculation came out like this - 20,290 BTUH sensible/8054 latent and the manufacture's specs states the unit's capacity is 23,000 BTUH sensible! 7000 BTUH latent, then you would have to find another unit, slow the fan, change coils or maybe even install a 3 ton unit, in order to cover the 8054 BTHU of latent heat gain.

R-Value

This is a number indicating the ability of a substance to resist the flow of heat. The higher the R value, the better it acts as an insulator.

Typical R-values of building components can be found in Manual J or go to: <http://www.coloradoenergy.org/procorner/stuff/r-values.htm> for a free listing of R-values.

U value

(Learn and understand U value. It is the foundation of a load calculation.)

The U value is the number of BTUs that pass through one square foot of substance in one hour's time when there is one degree temperature difference. The U value is the reciprocal* of the R value. A U-value can be said to be the *rate of conduction*

$$U=1/R$$

*A reciprocal of a number is 1 divided by the number. The reciprocal of 20 is 1/20 or .05.

Suppose you had a six-inch thick, R- 19 fiberglass insulation batt, and you wanted to know how much heat will pass through it. First, determine the U value.

$$U= 1/R$$

$$U= 1/19$$

$$U=.0526$$

Therefore, .0526 BTUs pass through 1 square foot of the batt each hour when there is one degree temperature difference.

If the batt measured 2' x 8' we would have a total area of 16 sq. ft. We could then say that .8414 BTUs (16 sq. ft. x .0526 BTUs). Pass through the entire batt in one hour when there is one degree temperature difference.

Carrying our example just one step further, if the temperature on one side of the batt is 20 degrees and on the other side it is 70 degrees, then we would have a 50-degree temperature difference (70–20). Therefore, 42.08 BTU's (.8414 BTU's x 50 degrees) would pass through the batt in one hour.

Simply stated, use the following formula to determine the amount of heat gained or lost through any substance:

$$\text{BTUH} = U \times \text{TD} \times \text{AREA}$$

$$=.0526 \times 50 \times 16'$$

$$= 42.08$$

Once you know the U value, the square footage and the temperature difference, you can calculate the BTU heat loss or gain per hour through a substance. However, walls, floors and ceilings are not made up of just insulation. A wall may be made up of brick, sheathing, insulation and sheetrock, each of which has its own R value. The R value of each component must be added together to obtain the total R value. Then we simply take the reciprocal (1/R) and get the total U value of the wall. For a list of R-values, locate a table

titled "**R Values of Common Building Materials**" in Manual J8, or go to:

<http://www.coloradoenergy.org/procorner/stuff/r-values.htm>

Below is an example of how to calculate the total R-value of a wall.

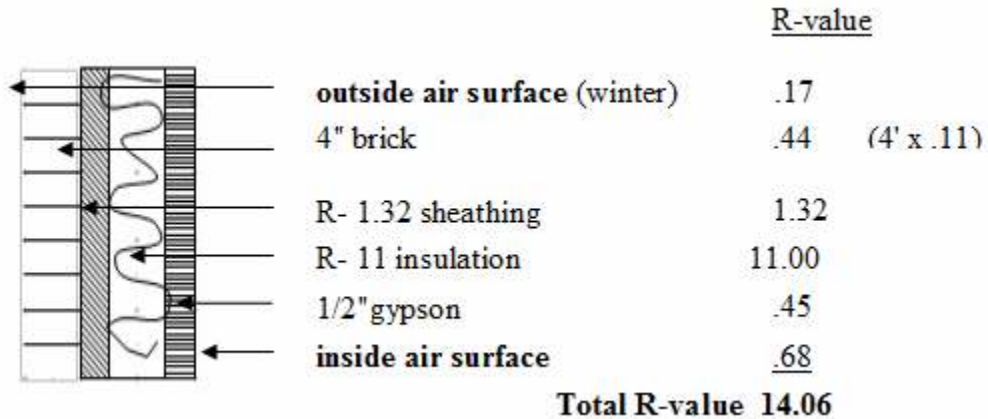


figure 3

*Note: On the test, **DO NOT FORGET TO ADD AIR FILMS** to get total R value.*

Now that you have the total R value, you can calculate the U value of the wall.

$$U = 1 / R$$

$$U = 1/14.06$$

$$U = .071$$

AND once you know (1) the U value, (2) the square footage of the wall, and (3) the design temperature difference (DTD), you can calculate the heat loss or heat gain through the wall.

As an example, let's say we're figuring the heat loss through the above wall. The wall is 40 ft. long and 9 ft. high. The wall is located in Birmingham, AL. What is the heat loss (BTUH)?

The formula BTUH = U x DTD x AREA

We know the U value = .071

The area = 40 ft. x 9 ft. = 360 sq. ft.

To get the DTD we need to go to Table 1, look up Birmingham, AL and find the outdoor winter design temperature, which is 23 degrees (figure 2). You were also told that unless otherwise stated, to use 70

degrees as the indoor winter design temperature. Therefore, the design temperature difference (DTD) is 70F - 23F = 47F.

Now complete the following simple calculation:

$$\begin{aligned} \text{BTUH} &= U \times \text{DTD} \times \text{AREA} \\ &= .071 \times 47 \times 360 \\ &= 1201 \end{aligned}$$

Now that you've calculated the heat loss through a wall you should be able to calculate the loss through the ceilings, floors, doors and windows exactly the same way.

What is an HTM?

The authors of Manual J attempted to simplify the mathematics of calculating the heat transfer through a buildings components (walls, ceilings, windows, etc) by eliminating U x DTD in the above formula. They came up with the term, *heat transfer multiplier*. The **HTM is the U value times the design temperature difference (DTD)**.

$$\begin{aligned} \text{HTM} &= U \times \text{DTD} \\ &= .071 \times 47 \\ &= 3.337 \end{aligned}$$

The formula for heat loss through a building component using an HTM is

$$\begin{aligned} \text{BTUH} &= \text{HTM} \times \text{AREA} \\ \text{BTUH} &= 3.337 \times 360 \\ \text{BTUH} &= 1201 \end{aligned}$$

The irony is; you still have to multiply the U-value x DTD in order to get the HTM

Notice the answer is the same whether using the *U x DTD x Area* or the

HTM x Area formula.

Note: Manual J worksheets require listing HTM's, Therefore, you must multiply each components U-value by the DTD and enter the resulting HTM in the HTM column.

Since Manual J8 does not give you the HTM. You must create your own HTM using the above formula. Go to Table 4A, construction number 16C-30. you will find a ceiling with R-30 insulation has a U

value of .032. To get the HTM for a 47 degree TD simply perform the following:

$$\begin{aligned}\text{HTM} &= \text{U} \times \text{DTD} \\ &= .032 \times 47 \\ &= 1.504\end{aligned}$$

To determine the heat loss through the ceiling (assume the ceiling area is 1678 sq.ft.):

$$\begin{aligned}\text{BTUH} &= \text{HTM} \times \text{AREA} \\ &= 1.504 \times 1678 \\ &= \mathbf{2524}\end{aligned}$$

So far we have talked about heat loss/gain through **conduction**. When calculating a heat loss/gain on a house we have to figure in all ways heat can be either lost or gained by the structure.

Another way heat is transferred either in or out of a structure is through **infiltration** and **ventilation** which heats or cools the air by **convection**. Infiltration occurs when outside air enters the building through cracks around windows, doors, receptacles, sole plates, etc. Ventilation occurs when we purposely force outside air in, either mechanically, such as using fans, or passively, such as opening a window. When outside air comes in by infiltration or ventilation, it must be considered part of the load calculation because this air has to be heated or cooled.

The following infiltration and ventilation discussion will address the **heat loss (winter)** calculation, however the principles remains the same for calculating heat gain.

Below is one of the most important formulas you will ever need in the HVAC business. We are going to spend some time on it not only because many test questions are based on it, but understanding it will make you a better HVAC professional.

$$\text{BTU} = \text{CFM} \times 1.1 \times \text{TD}$$

CFM – cubic feet per minute

1.1 – constant (amount of BTUs required to heat 1 cu. ft. of air 1 degree)

TD - temperature difference or design temperature difference

Let's start by calculating the heat loss due to **infiltration**. The infiltration rate, expressed in **air changes per hour**, is determined by using the results of a blower door test or making an educated guess by using Table 5A or 5B in Manual J. Let's use Manual J. Our home is 1678 sq. ft., single story of average construction with one semi-tight fireplace. According to Table 5A, the infiltration rate is .38 air changes per hour (ACH) plus 13 cfm for the fireplace.

To determine the heat loss due to infiltration we must use the following formula:

$$\text{BTU} = \text{CFM} \times 1.1 \times \text{TD}$$

1.1 is a constant and 47 is our TD. If we only knew the CFM we could plug it into the formula and get the BTUs needed to offset the infiltration. How do we get the CFM?

Answer: We must change *air changes per hour to cubic feet per minute* (CFM).

How to change air changes per hour to CFM.

$$\text{CFM} = (\text{VOLUME OF STRUCTURE} \times \text{AIR CHANGES PER HOUR}) / 60 \text{ MINUTES}$$

OR

$$\text{CFM} = \text{VOLUME OF STRUCTURE} \times \text{AIR CHANGES PER HOUR} \times .0167$$

Where:

Volume = length x width x height,

Or

Volume = area x height

.0167 is the decimal equivalent of 1/60

Therefore the volume of our house is 15,102 cu. ft. (1678 sq. ft. x 9 ft. high)

$$\text{CFM} = (15,102 \times .38) / 60 \text{ MINUTES}$$

$$\text{CFM} = 5739 / 60$$

$$\text{CFM} = 96 \text{ (rounded from 95.65)}$$

Add the fireplace

$$96 + 13 = \mathbf{109 \text{ CFM}}$$

Now that we have the mystery CFM figure, we can plug it into the infiltration formula to determine the house heat loss due to infiltration.

$$\text{BTU} = \text{CFM} \times 1.1 \times \text{TD}$$

$$\text{BTU} = 109 \times 1.1 \times 47$$

$$\text{BTU} = 5635$$

Calculating infiltration for air conditioning (heat gain).

When calculating the BTUH required to offset infiltration for air conditioning we must use two formulas. One to determine the *sensible* heat gain and another to determine the *latent* heat gain.

The formula below for sensible heat gain is the same for winter infiltration

$$\text{BTUH (Sensible)} = \text{CFM} \times 1.1 \times \text{TD}$$

While the formula for latent heat gain is

$$\text{BTUH (Latent)} = \text{CFM} \times .68 \times \text{Grains Difference}$$

.68 is a constant

Example: Using figure 2, find the out summer design temperature for Birmingham, AL. You are correct if you chose 92F. Assuming we would like to maintain 50% relative humidity in the home, we would need to remove 41 grains of moisture per lb of air (refer to figure 2). The TD is 17F (92F-75F). Now lets apply the two formulas

$$\text{CFM} = (\text{Volume} \times \text{ACH})/60$$

Table 5A shows the summertime ACH is .20 and there is no CFM gain for the fireplace

$$\text{CFM} = (15,102 \times .2)/60$$

$$= 3020/60$$

$$= 50.33$$

Now apply the two formulas

$$\text{Sensible heat gain (BTUH)} = \text{CFM} \times 1.1 \times \text{TD}$$

$$= 50.33 \times 1.1 \times 17$$

$$= 941 \text{ BTUH}$$

$$\text{Latent heat gain (BTUH)} = \text{CFM} \times .68 \times \text{grains diff.}$$

$$= 50.33 \times .68 \times 41$$

$$= 1402 \text{ BTUH}$$

The **total heat gain from infiltration** is 941 BTUH + 1402 BTUH = **2343** BTUH

Duct loss and duct gain

Before discussing duct losses and gains it must be pointed out that there are four versions of Manual J8 and it seems that the values in the charts have changed with each version, therefore if you see different figures then used in our example, go with the figures in your book.

Another way a house loses or gains heat is through losses in the duct system

Manual J8 has 23 pages of Table 7s. Let's use Table 7B-T for our illustration. Notice at the top of the page it describes the ductwork and location. In the BASE CASE HEAT LOSS FACTOR chart locate 20 degrees below the OAT heading. Slide to the right under the 1500 sq. ft heading and you will see of factor .180. This means the duct loss is 18% before any corrections for insulation values or leakage. Next, go to the R-VALUE CORRECTION chart (below), you will see a correction factor of 1.85 beneath R2. Next, go to the LEAKAGE CORRECTION chart and select a factor under R2. Since our ductwork is unsealed, select 1.53. (See section 1-8, J8 for an explanation of leakage options.)

To determine the duct loss factor, multiply:

BASE FACTOR x R-VALUE CORRECTION FACTOR x LEAKAGE
CORRECTION FACTOR.

$$.180 \times 1.85 \times 1.53 = .509$$

Our duct loss therefore is 50.9% of the total heat loss of the home.

Before you get too excited, we have one more adjustment to make. Take a look at the DEFAULT DUCT WALL SURFACE AREA chart. Under the 1500 sq. ft. column it states the surface area of the supply should be 312 sq. ft. and the surface area of the return should be 138 sq. ft. If our duct system is anything other than these dimensions, then we must apply another correction factor to the above calculated duct loss. Obviously, it is most unlikely the surface areas will be the same as the default areas, so here's how to make the adjustment:

Assume the actual surface area of the supply ducts is 267 sq. ft. and the return ducts are 95 sq. ft. Find the chart labeled SURFACE AREA FACTORS. Under the Ks column (supply) find a Ks factor of .607 and under the Kr column (return) find a Kr factor of .393. Now apply the following formula:

$$\text{SAA} = (\text{Ks} \times (\text{actual area/default area})) + (\text{Kr} \times (\text{actual area/default area}))$$

$$\begin{aligned}
 &= (.607 \times (267/312)) + (.393 \times (95/138)) \\
 &= (.607 \times .856) + (.393 \times .688) \\
 &= .519 + .270 \\
 &= \mathbf{.789}
 \end{aligned}$$

The duct loss before applying the surface area factor is .509. To get the adjusted duct loss, multiply the duct loss by the SAA.

$$\begin{aligned}
 \text{Final or adjusted duct loss} &= .509 \times .789 \\
 &= \mathbf{.401}
 \end{aligned}$$

Total heat loss of structure (before duct loss) = 43,678 BTUH

Duct loss factor = .401

.401 x 43,678 = BTUH duct loss

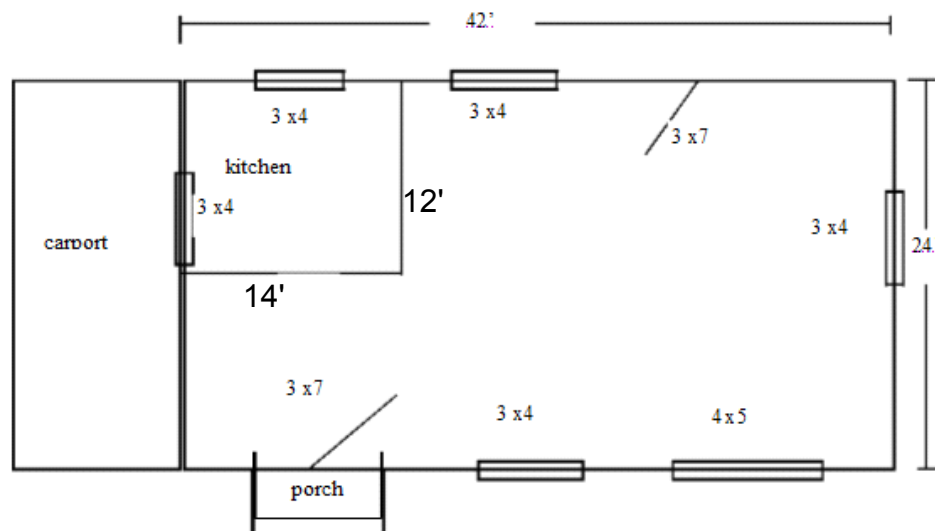
= 17,515 BTUH duct loss

Add duct loss to heat gain 17,515 + 43,678

Total heat loss with duct loss 61,193 BTUH

Let's do a *heat loss* calculation

The calculation we're about to do will be a whole house calculation. A *heat loss* calculation is made up of only three things; conduction losses, infiltration losses and duct losses. We are not going to try to teach you how to figure square footage or volume at this time. If you're having trouble with geometry you'll find help at the back of this book. For simplicity, our sample house is very small and simple. The principles would be the same however, even if it were the Vanderbilt mansion.



Sample House

LOCATION- RALIEGH		
Duct Loss use Table 7H Manual J8		
TRUNK AND BRANCH DUCT SYSTEM, LOCATED IN CLOSED CRAWLSPACE, R-2 INS, UNSEALED, Surface area of supply 260 sq.ft- return 98 sq.ft.		
INFILTRATION- Use Table 5A Manual J8		
TIGHTNESS OF CONSTRUCTION- AVERAGE		
8 FT. CIELINGS		
COMPONENT	J7 HTM	J8 HTM
WINDOWS – DOUBLE CLEAR GLASS WOOD FRAME	27.6 (TABLE 2 NO. 1A)	.57 X 50 DTD = 28.5 (TABLE 2A NO. 1 D)
DOORS- METAL POLYSTYRENE CORE WITH STORM	15.9 (TABLE 2 NO. 11 D)	.21 X 50 DTD = 10.5 (TABLE 4A NO. 11O)
WALLS- WOOD FRAME, R-1 1 INS, WOOD SHEATHING	4.5 (TABLE 2 NO. 12C)	.097 X 50 DTD = 4.85 (TABLE 4A NO.12B OS w/m)
CEILING- VENTILATED ATTIC, R-19 INS	2.6 (TABLE 2 NO. 16D)	.049 X 50 DTD = 2.45 (TABLE 4A NO. 16B-19)
FLOORS- ENCLOSED CRAWLSPACE, CARPET, NO INS	5.4 (TABLE 2 NO. 19F)	.295 X 18.8 = 5.55 use TD in Table 4A, const # 19A. do not use DTD

Figure 3

HEATING LOAD				
row		AREA/VOLUME	HTM	BTUH
1	solar gain			
2	gross walls	1056		
3	windows	80	28.5	2280
4	doors	42	10.5	441
5	net walls	934	4.85	4529
6	ceilings	1008	2.45	2469
7	floors	1008	5.55	5594
8	infiltration sensible (1)	8064	winter ACH .45	3326
9	people sensible	No.		
10	appliances			
11	sub total			18,639
12	duct loss 34% (2)		.34 x 18,639	6337
13	duct gain %			

Figure 4

1. Infiltration BTUH = CFM x 1.1 x DTD

$$\text{CFM} = (\text{house volume} \times \text{ACH}) / 60 \text{ minutes}$$

$$= (8064 \times .45) / 60 = 60.48$$

$$\text{BTUH} = 60.48 \times 1.1 \times 50 = \mathbf{3326 \text{ BTUH}}$$

2. Duct loss = Base loss x R-value correction x leakage correction x SAA

First determine the SAA (surface area adjustment)

$$\text{SAA} = (.682 \times (220/260)) + (.318 \times (98/84))$$

$$= (.682 \times .846) + (.318 \times 1.166)$$

$$= .577 + .371$$

$$= .948$$

$$.110 \times 1.63 \times 2.02 \times .948 = \mathbf{.343 \text{ (Rounded to 34%)}}$$

Explanation of heating load calculation

Rows 2-6 - Under area/volume, enter the area (sq. ft.) of each component of the home.

Enter the volume (cubic ft.) in the *infiltration* row

Row 7 - Floors over crawl space or unheated basement or elevated (such as beach house), enter the area (sq ft).

Slab floors on grade - enter the perimeter (linear feet of slab exposed to outdoor conditions)

Row 8 - Calculate the Sensible heat loss due to infiltration using formula 1. above and enter the result in the BTUH column. (Table 5A Manual J8 lists air changes per hour)

Row 9 - Leave No. of people blank, as people load is not considered with the heat loss calculation.

Under the HTM column, calculate and enter the HTM of each component in rows 3-7 using the U values in Manual J (Figure 3 references the Tables and construction numbers)

Multiply the values in the area column by the corresponding HTM and enter the result in the BTUH column

Row 11 - Add rows 3-8 and enter the result in the BTUH column

Row 12 - Calculate the duct loss using formula 2. above and enter the result in the BTUH column. Values are derived from Table 7H Manual J8.

Row 14 - Add the BTUH column in rows 3-12 and enter the result in the BTUH column. This is the total heat loss.

ROOM BY ROOM CALCULATION

A room-by-room load calculation must be performed in order to size the air distribution system. Each room will have a different load; therefore, a corresponding amount of air has to be delivered to each room to assure an even temperature throughout the house. Duct sizing and air distribution is discussed in a later chapter, "Three Easy Steps to Duct Sizing".

Performing a load calculation for an individual room is done in the same manner as a whole house calculation. You must, however, keep in mind to enter in the *area* column **only areas exposed to the outdoor temperature.**

For example, although the kitchen (12' x 14") has 52 linear feet of wall area, only 26 linear feet is exposed to the outdoors. Therefore enter 208 in the area column (26' x 8'). If the house were two stories, where the room above is heated, you would enter 0 area for the kitchen ceiling, as the ceiling is not exposed to the outside, but exposed to the heated second floor.

Infiltration is calculated differently when performing a room-by-room calculation. to allocate the correct amount of heat loss through infiltration for each room, first calculate the WAR (wall area ratio):

$$\text{WAR} = \text{exposed room wall area} / \text{whole house wall area}$$

then

$$\text{Room infiltration} = \text{WAR} \times \text{whole house infiltration}$$

example infiltration calculation for kitchen:

$$\text{Exposed wall area of kitchen} = 26' \times 8'$$

$$= 208 \text{ sq.ft.}$$

$$\text{war} = 208 / 1056$$

$$= .197$$

$$\text{room inf.} = .197 \times 3326$$

$$= 655 \text{ BTUH}$$

ROOM-BY-ROOM HEAT LOSS (Kitchen)

		AREA OR VOLUME	x HTM	= BTUH
1	GROSS WALL	208	XXXXXXXX	XXXXXXXX
2	WINDOWS	24	28.5	684
3	DOORS	0	10.5	
4	NET WALL	184	4.85	892
5	CEILING	168	2.45	412
6	FLOORS	168	5.55	932
7	INFILTRATION (whole house wall area)	1056	WAR .197	655
8	SUBTOTAL	XXXXXXXX	XXXXXXXX	3575
9	DUCT LOSS (.34)	XXXXXXXX	XXXXXXXX	1216
10	TOTAL HEAT LOSS	XXXXXXXX	XXXXXXXX	4791

The above calculation indicates the room heat loss of the kitchen is 4791 btuh. After calculating the heat loss of the kitchen, we must calculate the individual heat loss of all other rooms in the house. If your room by room calculation is correct, all of the room heat loads will add up to the whole house heat load (24,976 btuh).

The Heat Gain Calculation

A **heat gain (cooling) calculation** is much like a heat loss calculation except the heat is entering rather than leaving the house. We must also add in internal loads from appliances and people and solar gain through glass. In addition, a separate calculation must be done to determine the **latent heat load** (a **heat loss** calculation only determines the **sensible heat load**). We're going to try to make this as painless as possible.

As with heating, the first things we need to know are the design conditions. To determine the outdoor design temperature for cooling, go back to Table 1 (FIGURE 2). Look up BIRMINGHAM, AL. Use the column labeled summer, Cooling 1% dry bulb. You will see 92 degrees as the outdoor summer design temperature. We always use 75 degrees as the indoor design temperature for cooling (70 for heating). Therefore, the design temperature difference (DTD) is 17 degrees (92-75).

Turn to Table 4A, construction no. 12B-0s w/m. To the right, under U-value with wood studs, you will see .097 listed as the U value. When figuring a **heat loss** we could arrive at the correct HTM by simply multiplying the TD by the U factor ($HTM = U \times TD$). In the summertime, however, the TD is not exactly what it appears to be. Because of the effect of the sun's radiation beating against the wall and the wall's ability to store heat, the **effective temperature difference (ETD)** can be higher or lower than the actual outdoor temperature. In addition, the daily temperature range affects the rate of heat transfer through a construction component. Where you have a high (H) range such as Las Vegas, the daytime temperature may reach 90 but at nighttime it might fall to 60; the nighttime temperature helps take the load off the wall. In Miami the temperature range is low (L), 90 during the day 78 at night, resulting in not much help in reducing the load. Table 1A (figure 2) gives the daily range in the last column. Birmingham's daily range is medium (M)

The effective temperature difference, also called the **cooling temperature difference (CLTD)**, can be found in Table 4B.

Let's go back to Table 4A, construction no. 12B-0s w/m. The far right hand column indicates the wall is in Group B. Now go to Table 4B. The cell at the intersection of 15/M and B/wall indicates a CLTD of 24.1

To get the cooling HTM, use the following formula:

$$\text{COOLING HTM} = U \times \text{CLTD}$$

$$= .097 \times 24.1$$

$$= 2.34.$$

Solar gain through windows or glass

Heat is gained through glass by **conduction** and by solar **radiation**. There is a calculation about a mile long used to determine the HTM for glass. Fortunately Manual J has calculated the HTM's for glass in Table 3. Use this Table to obtain the HTM

In order to use the tables, you will need to know (1) the TD, (2) the type of glass, (3) the direction the glass is facing and (4) the area of glass that is shaded and unshaded.

Determine shaded/unshaded glass area

To determine the heat gain by glass we must separate the shaded area from the unshaded area, as each has a different HTM.

Try this exercise to determine the shaded/unshaded area of a south facing window.

Our sample window is 5 ft. high and 3 ft. wide, facing south. The overhang sticks out 18" and the top of the window begins 6" below the overhang (you may want to draw this out). The home is located 36 degrees north latitude.

Using Table 3E, fill in the blanks under column #1. A sample calculation may be found in Section 19 - 13. If you do all the math correctly, the results should show 14.37 sq. ft. shaded and .63 sq. ft. unshaded.

In our solar gain calculation below, all glass facing south will be partially shaded by the overhang. There is no overhang on the east side, so these windows are totally exposed to the sun and because the west facing windows are under a carport they will be totally shaded. The north facing windows are always shaded

Let's do the solar gain calculation for the window area

SOLAR GAIN THROUGH GLASS					
	Total glass	SHADED	UNSHADED	HTM	BTUH
NORTH	24	24			
NE/NW					
SOUTH	32	24	8	38	304
SE/SW					
EAST	12		12	73	876

WEST	12	12		
TOTAL NORTH AND SHADED		60		24
TOTAL SOLAR GAIN				2620

Use Table 3a-1, clear glass, double pane, no internal shading, 20F CTD, select the HTM's that correspond to the window direction.

The north window and the shaded portion of all other windows are added to the total shaded area. The HTM for **north and shaded** will always be the same.

All unshaded areas are multiplied by the corresponding HTM.

LOAD CALCULATION					
		HEATING		COOLING	
	AREA/VOLUME	HTM	HEAT LOSS	HTM	HEAT GAIN
1	solar gain				2620
2	gross walls	1056			
3	windows	80	28.5	2280	
4	doors	42	10.5	441	6.51
5	net walls	934	4.85	4529	2.82
6	ceilings	1008	2.45	2469	2.45
7	floors	1008	5.55	5594	2.21
8	infiltration sensible (1)	8064	winter ACH .45	3326	summer ACH .23

9	people sensible	No. 4			230	920
10	appliances					1200
11	sub total			18,639		13023
12	duct loss 34%			6337		
13	duct gain 22%					2865
14	total sensible load			24,076		15,888
15						
16	infiltration latent (2)	8064			summer ACH .23	861
17	duct gain latent (3)				see below	2462
18	people latent	No. 4			200	800
19	total latent load					4123
20	TOTAL LOADS		HEATING	24,976	COOLING	20,011

Row 8 (cooling column)

(1) Sensible Infiltration BTUH = CFM x 1.1 x TD

$$\begin{aligned}
 &= ((AC/HOURXVOL.)/60) \times 1.1 \times TD \\
 &= ((.23 \times 8064)/60) \times 1.1 \times 20 \\
 &= 30.9 \times 1.1 \times 20 \\
 &= 678
 \end{aligned}$$

Row 13

Duct gain = base case x R-value correction x leakage correction x SAA

First determine the SAA

$$\begin{aligned}
 SAA &= (.682 \times (220/260)) + (.318 \times (98/84)) \\
 &= (.682 \times .846) + (.318 \times 1.166) \\
 &= .577 + .371 \\
 &= \mathbf{.948}
 \end{aligned}$$

$$\text{duct gain} = .070 \times 1.63 \times 2.02 \times .948$$

$$= .218 \text{ (rounded to 22\%)}$$

Row 16

(2) The total heat gain of 15,888 BTUH per hour is just the **sensible heat gain**. Now we have to calculate the **latent heat gain**.

Latent heat as you will remember is the heat required to remove the moisture from the air. Infiltration of humid outdoor air and people are the main sources of moisture in a residence. People contribute about 200 BTUH of latent heat per person. The amount of latent heat brought in from outside air is dependent upon the CFM and its amount of moisture (measured in grains/lb. of air).

The formula for determining the latent heat due to infiltration is:

$$\text{BTUH} = \text{CFM} \times \text{GRAINS DIFFERENCE} \times .68$$

$$\text{CFM} = (\text{AIR CHANGES PER HOUR} \times \text{VOLUME})/60 \text{ min.}$$

GRAINS DIFFERENCE is the average amount of moisture (measured in grains) found in outside air at design conditions minus the amount of moisture required to achieve a satisfactory relative humidity inside. It takes 7005 grains to make a pound. Looking at Table 1, Birmingham, AL, you will see under grains difference a choice between 55%, 50% and 45% relative humidity. We will use the column under 50% (meaning we want to achieve 50% RH in the house) and find 41 will be the grains difference (the amount of moisture we need to remove from the inside air). Manual J is leaving it up to you to decide which RH to strive for. 55% should be the upper limit as mold and mildew will begin to become a problem above 60% RH.

.68 is a constant.

With the above information we can now calculate the latent heat gain of our sample house through *infiltration*.

$$\text{Latent heat gain (infiltration)} = \text{CFM} \times .68 \times \text{Grains Diff.}$$

$$= 30.9 \times .68 \times 41$$

$$= 861 \text{ BTUH}$$

ROW 17

(3) Duct gain (Latent heat). Because humid outdoor air can be sucked into ducts through leaks, this load must be taken into consideration. The formula is as

follows:

$$\text{Duct gain (latent)} = \text{base case latent heat} \times \text{leakage correction} \times \text{LGA}$$

Refer to Table 7H, use the closest values, 1000 sq. ft. for floor area, 40 for grains

$$\text{Duct gain (latent)} = 542 \times 4.02 \times (95/84)$$

$$= 542 \times 4.02 \times 1.13$$

$$= 2462 \text{ BTUH}$$

ROW 18

Latent heat produced by people. For sedentary people home use 200 BTUH per person - latent heat

$$\text{People (latent)} = \text{No. people} \times 200$$

$$= 4 \times 200 = 800 \text{ BTUH}$$

Peak Load Procedure

When to use the peak load procedure

The peak load procedure should be used to calculate room-by-room loads for *sizing ducts of zoned systems* (use time of *day* peaks) or, if the home has an unusually large amount of glass facing a particular direction especially south (use time of *year* peaks).

Generally, the only difference between an average load procedure (this is the procedure we have been discussing) and a peak load method is the HTM's for glass are higher. The most current edition of Manual J8 does not have peak load tables for glass, therefore, it is unlikely you will be tested on peak loads. However, Appendix 11 provides a formula for calculating the fenestration HTM's for peak times of day. Manual N may also be consulted to obtain peak load HTM's.

Important: when designing a zoned system, size the *equipment* using the average load procedure, but size the *ductwork* using the peak load procedure.

IMPORTANT NOTES

Wall, is it above or below grade?

Construction #15, Table 4A, deals with below grade walls (basement walls).

The wall must be at least two feet below grade to be considered a below grade wall (for example, a wall 1.5 feet below grade is considered an above grade wall).

Concrete slabs on grade

If the concrete slab is less than 2 ft. below grade then it is considered on grade. Use construction No. 22, Table 4A. A basement floor, less than 2 ft. below grade, is also treated as a slab on grade. Unlike a regular floor, for slabs *on grade*, you must multiply the *linear feet (do not use sq. ft.)* of the exposed edge by the HTM to get the heat loss. For example, a 10' x 20' slab on grade with R-5 insulation, construction No. 22B-5rh would have an HTM of 32.9 (.589 x 55) at 55 degree TD. The perimeter of the slab is 60 linear ft. (10+20+10+20=60). The heat loss is:

$$32.9 \times 60 = 1974 \text{ BTUH.}$$

Basement floors

A basement floor is any slab greater than 2 ft. below grade. To get the heat loss, multiply the HTM by the **sq. ft.**, just like a regular floor. Use construction No. 21, Table 4A. For example a basement floor measuring 28 x 50 with no insulation, 55 DTD.

$$\text{HTM} = 55 \times .022$$

$$= 1.21$$

$$\text{BTUH} = 1400 \text{ sq. ft.} \times 1.21$$

$$= 1694$$

