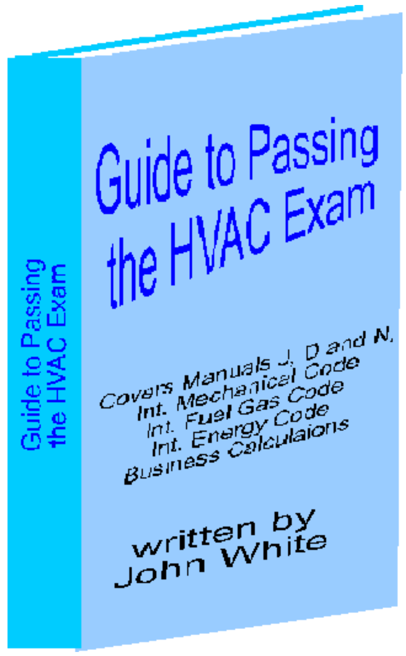


IMPORTANT STUFF

This manual has been designed as a supplemental aid for students preparing to take the state heating and/or air conditioning license exam. It is not intended to replace any manuals or material required for study. Furthermore, it is not an approved reference to carry into the exam room.

The student must obtain the following reference material in order to use this manual. These references may to be taken into the exam room.

International (or your state) Mechanical Code
International (or your state) Fuel Gas Code
ACCA- Manual J (seventh or eighth edition)
ACCA Manual N
ACCA- Manual D

Optional references

International (or your state) Energy Code
International (or your state) Residential Building Code

Questions or comments may be emailed to: **jrwmtw@gotricounty.com**

Revised 2011

ENERGY MARKETING SERVICE
374 Cattlelot Lane, Belhaven, NC 27810

A GUIDE TO MANUAL J 7th or 8th Edition

THE FOLLOWING DISCUSSION IS FOR MANUAL J8 USERS

Manual J8 was developed to provide two methods of calculating residential loads; the **average load procedure** and the **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, then 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 then 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, 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 mid summer data, the equipment might be undersized in October when the sun gets lower and begins radiating through the large amount of south facing glass.

The following is a discussion of the Average Load Procedure which is also the basis of Manual J7. A discussion of the Peak Load Procedure will follow afterward.

Why a guide to manual J?

For over 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, so lets get started.

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 cannot be completely stopped. For example, if you put 180-degree coffee in a thermos bottle, even if it is super insulated, sooner or later it will reach room temperature (lose heat). If you wanted to maintain the temperature of the coffee at 180 degrees then you would have to put heat to it. The problem is. "How much heat (BTUH) do you put to it to maintain the 180 degree temperature?" Too many BTU's will overheat it and too little will not keep it warm enough. To know the precise amount of heat we need, we would have to know exactly how much heat the thermos bottle is losing per hour through it's walls and cap. Then. we would apply exactly that amount of heat per hour.

A house, like a thermal insulated bottle, also losses or gains heat, depending on whether it’s winter or summer. If we know how much heat is being transferred through it’s 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.

Why do a load calculation?

The oblivious reason is to prevent installing a system that is too small to do the job. If this were true then 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, right, 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 cut off and on. It may satisfy the thermostat but leave other parts of the home either over or under heated, thus the occupants are 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 (cold spot), he will turn up the thermostat, wasting 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) 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 but 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'd 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 top of a refrigerator or water heater. Heat travels in all directions, through walls, floors and ceilings at the same rate.

BTU

The amount of heat required to raise the temperature of one pound of water one degree F.

BTUH

The amount of heat required to raise the temperature of one pound of water one degree F in <u>one hours time.</u>

SPECIFIC HEAT

The amount of heat required to raise the temperature of one pound 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.)

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 (BTU's) required to raise the temperature of a substance use the following formula.

BTU (sensible) = lbs. X temp diff. X 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

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

Design temperature and design temperature difference (TD)

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 1 in manual J will provide you with the outdoor conditions for major cities in the United States. Find the city that closest represents your area and use Table 1 figures. Use 97-1/2% (99% J8) design column for winter and the 2-1/2 % (1% J8) column for summer.

NOTE 1: If you feel the temperatures in manual J are not true representations then use other data or experience but do not go overboard. (On test use Manual J figures)

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 then 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 Raleigh

70F- 20F (OD temp found in table 1)=50 DTD

LATENT HEAT

Latent heat is heat required to change the state of a substance. 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. But when we change the state of the water from liquid to vapor (steam) we are not changing the temperature, only the state (water can exist as liquid or steam at 212 degrees F), but it takes energy or BTU's to do the job. 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.** 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 produce by the air conditioner then it would take 12,120 BTUH of capacity to produce the latent heat necessary to remove the moisture.

Water weighs 8.33 lbs./ gal.
8.33 lbs/gal. X 1.5 gals = 12.5 lbs.
12.5 lbs. X 970 btus/lb.= 12,120 BTU's (latent heat)

NOTE: When calculating heat gain (air conditioning) two loads are figured. One is sensible heat and the other is latent heat. 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 manufactures 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 manufactures specs says the units capacity is 23,000 BTUH sensible! 7000 BTUH latent, then you would have to find another unit, capable of supplying the 8054 BTU's of latent heat even if you must use a larger unit.

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.

U value (learn and understand this, it is the foundation of a load calculation)

The U value is the number of BTU's that pass though 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

U=1/R

*A reciprocal of a number is 1 divided by itself. 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 BTU's 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 BTU’s (16 Sq. Ft. X .0526 BTU’s). 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.

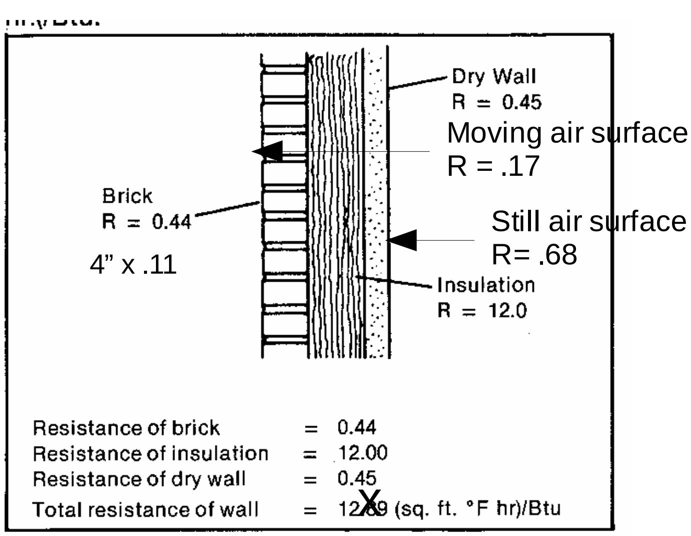
Simply stated, to determine the amount of heat gained or lost through any substance

BTUH=U X AREA X TD

=.0526 X 16' X 50 TD

= 42.08

Ok, now you've learned if 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. A wall floor or ceiling is not made up of just insulation however. A wall may be made up of brick, sheathing, insulation and sheetrock, each of which has it's 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. Manual J7 section VII paragraph 7-8 (This illustration is not in J8, but you need to know this) attempts to show you one such wall with its composite R values **(R-values of common material are listed in Table 10 for J7 or Table A51 for J8).** Using Manual J's illustration, it shows a total R value (resistance) of 12.89. This illustration is misleading. You must also add the R value of air films, both inside and outside of the wall (read paragraph 7-10). The illustration should look like this.



ACCA Manual J, 7th edition

Illustration does not show air surfaces

Should be as follows:

Moving air film	.17
Brick	.44
Insulation	12.00
Dry wall	.45
Still air film	.17
Total resistance	R 13.23

Air films must be included to get total R-value

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= 1/13.23
U=. 076

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

As an example. Lets 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 Durham, NC. What is the heat loss (BTUH)?

The formula BTUH = U X AREA X TD

We know the U value = .076

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

To get the TD we need to go to Table 1, look up Durham, NC and find the outdoor winter design temperature, which is 20 degrees. You were also told that unless otherwise stated to use 70 degrees as the indoor winter design temperature. Therefore the TD is 70F-20F = 50F.

Now complete the simple calculation below.

BTUH=U X AREA X TD

=.076 X 360X 50
= 1368

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.

Here's the good news(J7 only) Tables 2 and 4 do lot of work for you. Lets say you have a 1678 sq. ft. ceiling with R 30 insulation under a ventilated attic and you want to know the heat loss through it at 55 degree design temperature difference (DTD). First go to Table 2 (winter) NOT Table 4 (cooling). Thumb through the table until you find a ceiling that matches the one your working with. In this case it would be construction number 16-G. Slide your finger across the top to 55 degrees, then down to the bin corresponding to line G and you see 1.8. Manual J refers to the number as the HTM (heat transfer multiplier). **The HTM is simply the U value times the design temperature difference (DTD).**

HTM=U X DTD

Therefore, if you know the construction characteristics of the walls, floors, ceilings, doors and windows, all you have to do is look up the HTM and multiply it by the area. Our ceiling described above would have a heat loss of:

BTUH = HTM X AREA

BTUH= 1.8 X 1678

BTUH=3020

NOTE: Suppose the temperature difference is 53 degrees. You will notice the TD's are only given in 5 degree increments; therefore, the HTM for 53 degrees is not listed. What do you do? If you slide your finger to the last column on the right you will see the column is labeled **U.** Go down to construction number 16-G and you will see a U factor of .033.

HTM=U X DTD
HTM=.033 X 53
HTM= 1.75

Now for the bad news (J8 only). Manual J8 does not have the tables mentioned above which give you the HTM, but it does have Table 4A which give the U value of various construction components You must create your own HTM using the above formula.
Go to Table 4A, construction number 16C-30. This is approximately the same ceiling as used for the J7 illustration above. Under the column labeled U-value, you will find a ceiling with R-30 insulation has a U value of .032. To get the HTM for a 55 degree TD simply perform the following:

HTM=U X DTD
=.032 X 55
= 1.76

To determine the heat loss through the ceiling:

BTUH = HTM X AREA
= 1.76 X 1678
= 2953

INFILTRATION AND VENTILATATION

So far we have talked about heat loss/gain through **conduction.** Conduction is the process of heat transferring it's energy from one surface of a substance to the other. If you place a spoon in a hot cup of coffee sooner or later the heat will work it's way up to the handle by 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.** 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 only. 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: It will make you a better HVAC professional.

BTU=CFM X 1.1 X TD

CFM – cubic feet per minute

1.1– constant (amount of BTU'S 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.** Unless we use highly accurate scientific instruments the amount of infiltrated air entering a house is only an educated guess.

Turning to Manual J7, Section III, Table 5 (J8, Table 5A) you will see the top section labeled *winter air changes per hour*. Let's say our house is of BEST tightness and is 1500 sq. ft., 9 ft. ceilings with one fireplace. The design temperature difference is 55 degrees. Locate where 1500 sq. ft. and BEST intersect and you will see .3. Add a fireplace (.1) and you have a total of .4 (.3 +. 1 = .4). This means the house will experience .4 air changes per hour. Our job is to determine how many BTUH we need to make up for this infiltration loss.

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

BTU = CFM X 1.1 X TD

1.1 is a constant and 55 Is our TD. If we only knew the CFM we could plug it into the formula and get the BTU's 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

CFM = (VOLUME OF STRUCTURE X AIR CHANGES PER HOUR)/60 MINUTES

OR

CFM = VOLUME OF STRUCTURE X AIR CHANGES PER HOUR X .0167

Volume = length X width X height,

Or

Volume = area X height

.0167 is the decimal equivalent of 1/60

Using our volume formula, the volume is 13,500 cu. ft. (1500 sq, ft, X 9 ft. high)

CFM = (13,500 x .4)/60 MINUTES

CFM= 5400/60

CFM=90

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.

BTU=CFM X 1.1 X TD
BTU= 90 X 1.1 X 55
BTU = 5445

Looking at the bottom of Table 5 (J7 only) you will see (in their example) an HTM of 70.6. **If you were to perform a *whole house* heat loss calculation (sometimes called a block load) you would not need to calculate the INFILTRATION HTM** (Simply insert 5445 BTUH in cell 7C below) . However when performing a ***room-by-room*** calculation you must determine an HTM in order to determine the infiltration loss for ***each*** room. To get an infiltration HTM divide the *whole house* infiltration by the total square footage of the windows and doors. For example, in our above house lets say it had 240 sq. ft of windows and doors. The HTM would be:

INFILTRATION HTM = WHOLE HOUSE INFILTRATION BTU/TOTAL WINDOW AND DOOR AREA

HTM = 5445/240

HTM = 22.7

So, what do you do with this infiltration HTM?
You multiply the window and door area of each room by the HTM in order to determine the infiltration loss of each room. Suppose we have two identical sized rooms. Room A has 20 sq. ft. of windows and room B has 80 sq. ft. of windows and doors. Which room would likely have more heat loss due to infiltration? Room A is losing 454 BTUH (22.7 X 20) vs. room B with a 1816 BTUH loss (22.7 X 80).

Ventilation calculations are a whole lot easier than infiltration. When we ventilate we are bringing in a specific amount of air (CFM). For example, if the outdoor air temperature is 20 degrees and the indoor temperature is 70 degrees and we bring in 300 CFM of outdoor air, what is the heat loss due to ventilation?

Use the **same** formula as for infiltration:

Answer: **BTUH = CFM X 1.1 X TD**

BTUH = 300 X 1.1 X 50

BTUH = 16,500

Duct loss and duct gain

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

Using the following description, we will calculate the duct loss using both J7 and J8 methods. Notice the difference in the results:

The ductwork is in the attic, it's an unsealed, trunk and branch configuration and located in an area where the outdoor temperature does not get below 16 F. The return is near the equipment and the supply outlets are in the center of the room. Assume the air temperature in the supply is 110 F and the ducts are insulated with R-2 and the outdoor design temperature is 20 F.

J7 users only

Manual J7 has two tables; **7A for duct loss** (winter) multipliers and **7B for duct gain** (cooling) multipliers. Be sure to use the correct table. Simply put, once you calculate the total heat loss or gain multiply the total BTUH by the duct loss multiplier and add it to your calculation.

Using Table 7B, we will use Case 1 (SA temp below 120F), then go to the far right column (winter design temp above 15F). Our ducts are in the attic with R-2 insulation, therefore, the multiplier is .15

Example:	Total heat loss of structure	43,678 BTUH
	Duct loss	.15
Solution	.15 X 43,678 = 6552 BTUH duct loss	
	Add duct loss to heat gain	6552 + 43,678
	Total heat loss with duct loss	**50,230 BTUH (J7)**

Manual J8 users only

Manual J8 has 23 pages of Table 7's. Let's use Table 7A-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 of .170. This means the duct loss is 17% before any corrections for insulation values or leakage. Next, go to the R-VALUE CORRECTION chart (below), you will see a correction factor of 1.84 beneath R2. Next go to the LEAKAGE CORRECTION chart and select a factor under R2. Since our ductwork is unsealed select 1.52. (see section 1-8, J8 for explanation of leakage options)

To determine the duct loss factor, multiply;

BASE FACTOR **X** R-VALUE CORRECTION FACTOR **X** LEAKAGE CORRECTION FACTOR.

.170 X 1.84 X 1.52 = .475

Our duct loss therefore is 47.5% 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 says the surface area of the supply should be 177 sq. ft. and the surface area of the return should be 43 sq. ft. If our duct system is anything other than these dimensions than 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 140 sq. ft. and the return ducts is 54 sq. ft. Find the chart labeled SURFACE AREA FACTORS. Under the Ks column (supply) find a Ks factor of .613 and under the Kr column (return) find a Kr factor of .387. Now apply the following formula:

SAA = (Ks X (actual area/default area)) + (Kr X (actual area/ default area))

= (.613 X (140/177)) + (.387 X (54/43))

= (.613 X .791) + (.387 X 1.256)

= .485 + .486

= .971

The duct loss before applying the surface area factor is .475. To get the adjusted duct loss, multiply the duct loss by the SAA.

Final or adjusted duct loss = .475 X .971

= .461

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

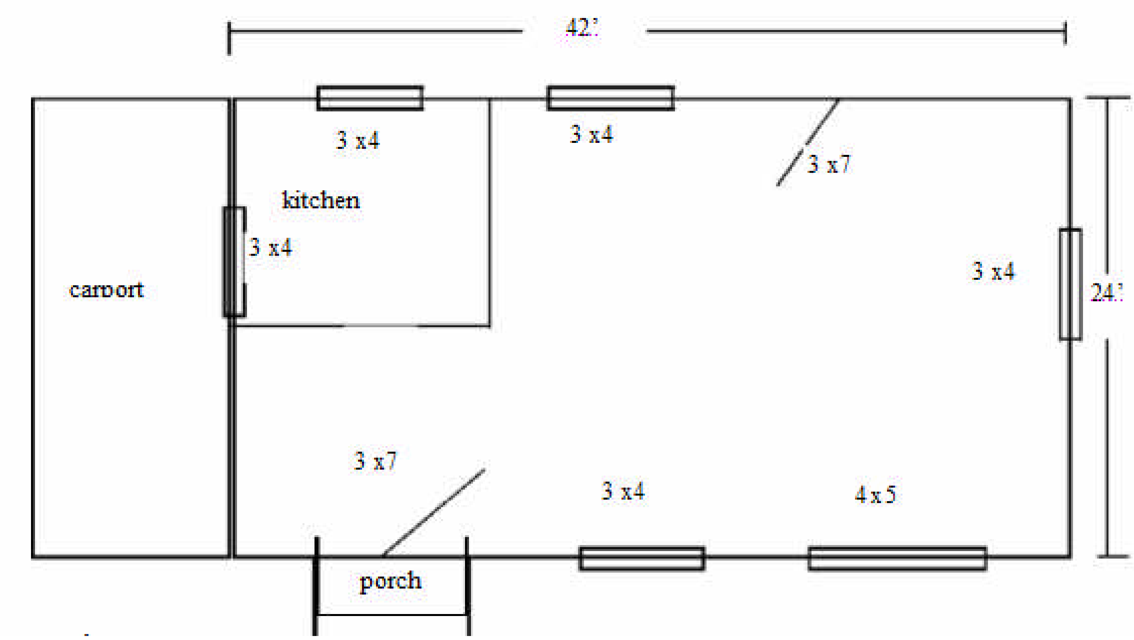
Duct loss factor = .461

.461 X 43,678 = 20,135 BTUH duct loss

Add duct loss to heat gain	20,135 + 43,678
Total heat loss with duct loss	**63,813 BTUH (J8)**

Let's do a heat loss calculation

The calculation we're about to do will be a *whole house* calculation. Manual J's example is a *room by room* calculation. It uses up a lot of paper and ink and makes the calculation look a lot harder than it really is. 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		
DUCTS LOCATED IN VENTED CRAWLSPACE, R-2 INS, UNSEALED,110F SUPPLY AIR, TRUNK AND BRANCH		
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 0S 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 A

1. The first thing to do is determine the **design temperature difference** (DTD). We will need the DTD in order to lookup or calculate the HTM for each building component. Since the house is located in Raleigh, NC, we will have to go to table 1 to look up the outdoor design temperature. The correct temperature is 20 degrees. Therefore the DTD is 50 (70 degree indoor temperature –20 degree outdoor temperature)
2. In column A (figure B below) enter the **square footage** of each building component. On line 7 enter the house **volume** instead of sq. ft.
3. In column B enter the HTM. Go to Table 2 (J7) or Tables 2 and 4A (J8), find the component that most closely matches our description and enter the HTM listed under 50 degree TD. (The chart above (figure A) shows the calculated HTM.s and gives reference to their origin.)
4. Column C is the product of columns of A and B (AX B). This gives you the total heat loss of each component.
5. In cell 7C use the infiltration calculation at bottom of chart to get the infiltration loss and enter it in the cell. Use Table 5, J7 (Table 5A, J8) to obtain air changes. **NOTE: the Table in J7 indicates 1 A/C per hour, While J8 indicates .75 A/C per hour. Our example is based on the J7 data.**
6. Add columns 2C thru 7C and enter answer in 8C. This would be the total heat loss of the house if it did not have a duct system or the duct system is in the conditioned space. (ducts in conditioned space have zero heat loss/gain.)
7. Duct loss: when ducts are located in unconditioned area
   Using J7:From the description of the duct system go to table 7a and determine the duct loss. Enter the figure in the quotation marks next to **DUCT LOSS** and multiply the sub total (8C) by the duct loss (.10). Enter the answer in cell 9C.

8. Add the sub total (8C) and duct loss (9C) and enter answer in cell 10C.

HEAT LOSS CALCULATION

		A	B	C
		AREA OR VOLUME.	**X HTM**	**= BTUH**
1	**GROSS WALL**	1056	**XXXXXXXX**	**XXXXXXXXX**
2	**WINDOWS**	80	27.6	2202
3	**DOORS**	42	15.9	668
4	**NET WALL**	934	4.0	3736
5	**CEILING**	1008	2.6	2621
6	**FLOORS**	1008	5.4	5443
7	**VOLUME (INF)**	8064	SEE BELOW	7392
8	**SUBTOTAL**	**XXXXXXXX**	**XXXXXXXX**	22,062
9	**DUCT LOSS (** .10 **)**	**XXXXXXXX**	**XXXXXXXX**	2206
10	**TOTAL HEAT LOSS**	**XXXXXXXX**	**XXXXXXXX**	24268

Figure B (Calculation based on J7 HTM.s and duct loss, J8 data may be substituted)

INFILTRATION = (AC/HR X VOL ./60) X 1.1 X TD

= (1 X 8064/60) X 1.1 X 50

= 134.4 X 1.1 X 50

= 7392 BTUH

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 our *Guide 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 column A, only areas *exposed* to the outdoor temperature. For example, although the kitchen has 52 linear feet of wall area, only 26 linear feet is exposed to the outdoors. 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 Rather than room volume, enter in cell A7, the total area of all windows and doors in the room. In column B enter the HTM as calculated below the heat loss form.

ROOM-BY-ROOM HEAT LOSS

(Kitchen) A B C

		AREA OR VOLUME.	XHTM	=BTUH
1	GROSS WALL	208	XXXXXXXX	XXXXXXXX
2	WINDOWS	24	27.6	662
3	DOORS	0	15.9	0
4	NET WALL	184	4.0	736
5	CEILING	168	2.6	437
6	FLOORS	168	5.4	907
7	INFILTRATION (window and door area)	24	61	1464
8	SUBTOTAL	XXXXXXXX	XXXXXXXX	4206
9	DUCT LOSS (.10 %)	XXXXXXXX	XXXXXXXX	421
10	TOTAL HEAT LOSS	XXXXXXXX	XXXXXXXX	4627

Inf. HTM = whole house infiltration / total area of windows and doors

HTM = 7392/122

= 61

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.

Manual J7 users only (next five paragraphs)
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. Look up Raleigh NC. Use the column labeled *summer, 2 1/2% Design db.* 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 4, construction No. 12 D. To the left you will see the HTM's listed under the various TD's and L M H. To the far left is the U factor (.080). When figuring a **heat loss** we could arrive at the correct HTM by simply multiplying the TD by the U factor (HTM=U X TD). In the summertime, however, the TD is not exactly what it appears to be.

As calculated above, our TD is 17 degrees, however, 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.

Because of all the parameters involved to determine an ETD, it is best to just use the HTM listed in Table 4. Use the next higher TD

Since our TD is 17, we must use 20 (Table 4 does not list HTM's for 17 degree TD). The daily range (L M H) can be found in the last column of Table 1; for Raleigh it is medium (M). Therefore, the **HTM for the wall is 1.9.** HTM's for doors, ceilings and floors are found in the same manner.

Manual J8 users only (next 5 pargraphs)

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. Look up Raleigh NC. Use the column labeled *summer, Cooling 1% dry bulb.* You will see 90 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 15 degrees (90-75).

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 X 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.

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:

COOLING HTM = U X CLTD

=.097 X 24.1

= 2.34

Note: our sample heat gain calculation will be calculated using Manual J7 data. J8 data will be in parenthesis.

Solar gain through windows or glass

Heat is gained through glass by **conduction** (glass has a U factor) and by solar **radiation.** There is a calculation about a mile long used to determine the HTM for glass. We are not going to discuss it here. Just use Table's 3 in either J7 or J8 to obtain an 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

The area of glass that is shaded and unshaded is the toughest thing to calculate (we're talking about outside shading due to the roof overhang). section V, paragraph 5-2 of

Manual J7 gives one explanation for calculating shaded area. Table 8 gives you a form for the calculation. Manual J8 uses the same form, which is found in table 3E. Below, we will give another way (hopefully easier) to calculate the shaded/unshaded area.

> Our sample window is 5 ft. high and 3 foot 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 40 degrees north latitude
>
> To determine where the shade line hits the window do the following:
> Multiply the distance the overhang sticks out by the Shade Line Multiplier in Table 8 (J7) or Table 3E (J8).
>
> 1.5 ft. X 2.60 = 3.9 ft.
>
> This means the shade line falls 3.9 ft (aprox. 3' 10") below the overhang
>
> Since the first 6" below the overhang is wall, then it leaves 3' 4" (aprox 3.3ft.) shading the window.
>
> 3'10" - 6" = 3'4"
>
> The window is 3 feet wide, therefore;
>
> 3.3' X 3' = **9.9 sq. ft**. is shaded or considered facing **north**
>
> Since the total area of the window is 15 sq. ft. (3' X 5'), it would leave **5.1 sq.** ft. (15'-9.9') unshaded or facing **south**.

In our solar gain calculation below, all glass facing south will be totally 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: calculation is from J7 data, HTM’s in ( ) are from J8 data @15 DTD

Use Table 3A, Tinted (heat absorbing) Glass. The windows are double pain.

Solar Gain calculation

Direction window is facing	AREA	HTM	BTUH (solar gain)
East	12	46(49)	552
West	0	46 (49)	0
South	0	25 (26)	0
North or shaded*	68	16(17)	1088
Total solar gain (BTUH)			1640

*The HTM for **north and shaded** will always be the same.

HEAT GAIN CALCULATION

The calculation below is performed using J7 data, numbers in ( ) are J8 HTM's. The following explanation for obtaining the HTM for the doors is representative of obtaining all J8 HTM's. **Remember, J8 recommends a 15 DTD, While J7 is based on a 20 DTD**

DOORS- METAL POLYSTYRENE CORE WITH STORM	J8 TABLE 4A NO. 11-O	.21 X 26 CLTD = 5.46

WALLS- WOOD FRAME, R-11 INS, WOOD SHEATHING	J8 TABLE 4A NO.12B 0S w/m	.097 X 24.1 CLTD = 2.34 (TABLE 4A NO.12B 0S w/m)

		AREA OR VOLUME	X HTM	= BTUH
1	**SOLAR GAIN**	XXXXXXXX	XXXXXXXX	1640
2	**GROSS WALLS**	1056	XXXXXXXX	
3	**WINDOWS**	80	XXXXXXXX	
4	**DOORS**	42	7.5 (5.46)	315
5	**NET WALLS**	934	1.9 (2.34)	1775
6	**CEILING**	1008	2.3 (2.45)	2318
7	**FLOORS**	1008	0	0
8	**VOLUME (INF)**	8064	SEE BELOW	1478
8	**NO. PEOPLE**	4	300	1200
10	**APPLIANCES**	XXXXXXXX	XXXXXXXX	1200
11	**SUB TOTAL**	XXXXXXXX	XXXXXXXX	8926
12	**DUCT GAIN (**.10 (.29))	XXXXXXXX	XXXXXXXX	893
13	**TOTAL HEAT GAIN (SEN.)**	XXXXXXXX	XXXXXXXX	9819

INFILTRATION=(AC/HOURXVOL./60)X 1.1 XTD =(.5X8064/60)X 1. 1X 20

=67.2X 1.1 X20

= 1478

The total heat gain of 9819 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 250 BTUH of latent heat per person. The amount of latent heat brought in from outside air is dependent upon the CMF and it's amount of moisture (measured in grains! Cu. Ft. of air).

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

BTUH = CFM X GRAINS DIFFERENCE X .68

CFM = (AIR CHANGES PER HOUR X VOLUME)/60 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, Raleigh NC, you will see under *grains difference* a choice between 50% (45% for J8) and 55% relative humidity. We will use the column under 50% (meaning we want to achieve 50% RH in the house) and find 40 (45 in J8) 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.

Manual J7 specifies an occupant load of 300 btuh sensible and 230 btuh latent

Manual J8 specifies an occupant load of 230 btuh sensible and 200 btuh latent

LATENT HEAT

		BTUH
LATENT HEAT (PEOPLE)	4 people X 230 BTU'S	920
LATENT HEAT (INFILTRATION)	CFM X GRAINS DIFF X .68 67.2 X 40 X .68	1828
TOTAL **LATENT** HEAT BTUH		2758

THE TOTAL HEAT GAI N= 9819 BTUH (SENSIBLE) + 2758 BTUH (LATENT)
12,577 Total BTUH

NOTE: Remember this is only a sample house. The window area is far less than that of a typical house. A typical house would likely have more window area, hence, a larger heat gain.

Peak Load Procedure (Manual J8 only)

When to use the peak load procedure

Use the peak load procedure to perform a room-by-room calculation ***when zoning.*** The room load is used only to size ducts. Use the ***average load procedure*** (the procedure we have been discussing) to size the equipment.

If the home has an unusually large amount of glass facing a particular direction (especially south) then a peak load, based on time of year, would be necessitated. You would then compare the *peak load* calculation to the *average load* calculation and install a unit capable of covering the largest of the two loads.

A peak load is only calculated for the *cooling load,* and only two things change when performing a peak load.

1. The HTM of **glass.** Use Table 3F for the peak CLTD.
2. The temperature difference (CLTD) used for calculating the HTM of **walls.** Use Table 4C the get the peak CLTD.

IMPORTANT NOTES

(J7 only) For **mobile homes** do **not use table 2 and 4** for HTM's, use appendix A-1.

(J7 only) For **multi family structures** (apartments and condos) **use appendix A-3 to obtain air changes** when calculating infiltration. Do not use Table 5

(J7 only) ***Footnotes to Table 2*** include 1 5 footnotes that should not be overlooked. We suggest you read and become familiar with all of them.

Wall, is it above or below grade?

Construction #15 in both manuals deal with below grade walls (basement walls)

> **Rule #1** The wall must be at least two feet below grade to be considered a below grade wall.(ie. A wall 1 .5 feet below grade is considered an above grade wall)
>
> **Rule #2** When measuring a below grade wall, measure from the actual grade level to the basement floor, then select ***2'-5' below grade*** or ***more than 5' below grade***

Concrete slabs on grade

If the concrete slab is less than 2 ft. below grade then it is considered on grade. A basement floor less than 2 ft. below grade is also treated as a slab on grade. Unlike a regular floor, 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. 22-B **using J7)** would have an HTM of 22.5 at 55 degree TD. The perimeter of the slab is 60 linear ft. (10+20+10+20= 60). The heat loss is 22.5 x 60 = 1350 BTUH.

Using J8, the construction number would be 22B-5pm. The HTM would be 24.7 (449 X 55 = 24.7)

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.

THE NEXT FIVE PAGES COVERING OPERATING COST AND HEAT PUMP BALANCE POINTS ONLY APPLY TO MANUAL J7 USERS. However, it wouldn't hurt for everyone to read on.

OPERATING COST

HEATING

Comfort and operating costs are the most important considerations of your customers when choosing an HVAC system. As a contractor you should be able to correctly size equipment, design the air distribution system and perform a quality installation job. As an *expert* you should be able to advise customers of their options for saving money, whether, it's adding insulation, increasing equipment efficiency or even changing fuels.

DEGREE DAY METHOD

Appendix A-4, Manual J offers a number of methods to calculate operating costs. The *degree day* method is the oldest and easiest method to use. It can be used to calculate operating cost for fossil fuel equipment (gas or oil), and electric furnaces. It should not be used for heat pumps. Paragraph A-4-3 gives the formula for the degree day method. It reads like this:

$$\textbf{Annual fuel consumption} = \frac{\textbf{House heat loss X degree days X 24}}{\textbf{Efficiency of furnace X btu content of fuel X DTD}}$$

Lets figure the operating cost for heating our sample house using and 80% AFUE natural gas furnace. Gas price is $1.50 per hundred cubic feet (therm). Since the house is located in Raleigh NC, look up the degree days in Table 1.

$$\textbf{Fuel} = \frac{\textbf{24,268 btus X 24 X 3440 degree days}}{\textbf{.80 efficiency X 1025 btus/cu. ft. X 50 degrees DTD}}$$

$$= \frac{\textbf{2,003,356,608}}{\textbf{41,000}}$$

$$= \textbf{48.867cu. ft. gas / year}$$

Since gas is sold per hundred cubic feet (therm), we must divide 48,867 by 100 in order to get therms.

Therms = 48,867btu/100 cubic ft. gas

= 488.67

Annual operating costs = 488.67 therms X $1.20
$586.40 per year

Before going any further, it is appropriate to understand a few terms used to determine operating costs

Efficiency-

AFUE (Annual fuel utilization efficiency)- This is the overall efficiency of a fossil fuel furnace including its' start up stack losses. Expressed as a percentage.
SEER (Seasonal energy efficiency ratio) – This is the average number of BTU's an air conditioner will produce for each watt of energy consumed. An air conditioner with a SEER of 12 will produce 12 BTU's per watt input
HSPF (Heating seasonal performance factor) – This is the average number of BTU's a heat pump will produce for each watt of energy consumed. A heat pump with an HSPF of 7 will produce 7 BTU's per watt input. Although it's popular to sell heat pumps by their SEER rating, it is equally important to promote it's HSPF as this is the wintertime heating efficiency. In addition, just because a heat pump might have a higher SEER rating than a competing one, it may not necessarily have a higher HSPF rating. In fact it could be lower. It pays to check both ratings.

Comparing efficiencies

To determine the operating cost of one system vs. the other use the following formula:

$$\textbf{Operating cost of new system(B)} = \frac{\textbf{Efficiency of system A X Operating cost of system A}}{\textbf{Efficiency of system B}}$$

EXAMPLE:

If the annual cooling cost of a 10 SEER A/C were $500, what would it be with a 12 SEER A/C?

Solution: Assume the 10 SEER system as **A** and the 12 SEER system as **B.**

$$\text{New operating cost} = \frac{10\text{ SEER X }\$500}{12\text{ SEER}}$$

$$= \frac{5000}{12}$$

$$= \$416$$

To compare operating cost of furnaces use AFUE instead of SEER and for heat pumps use HSPF.

Degree day

Suppose Monday night it got down to 25 degrees outdoors and later in the afternoon the temperature rose to 63 degrees. Then the average temperature for the day would be 44 degrees (63+25=88, 88/2 = 44). Typically we do not need to heat our house unless the outdoor temperature gets below 65. Therefore we use 65 degrees as a base temperature. When we subtract the average temperature from 65 the result in this case is 21 degrees. These 21 degrees are called *21 degree days.* If we took Tuesday's average temperature and subtracted it from 65 we will come up with another number, say 41 degrees, or *41 degree days.* If we add all the degree days for each day in the year the total would represent how cold an area is. Raleigh, NC has 3440 degree days while Duluth, MN has 9890. Oil and LP gas companies use degree days to determine when to deliver their product. We use degree days to determine operating costs.

Heat pump balance point

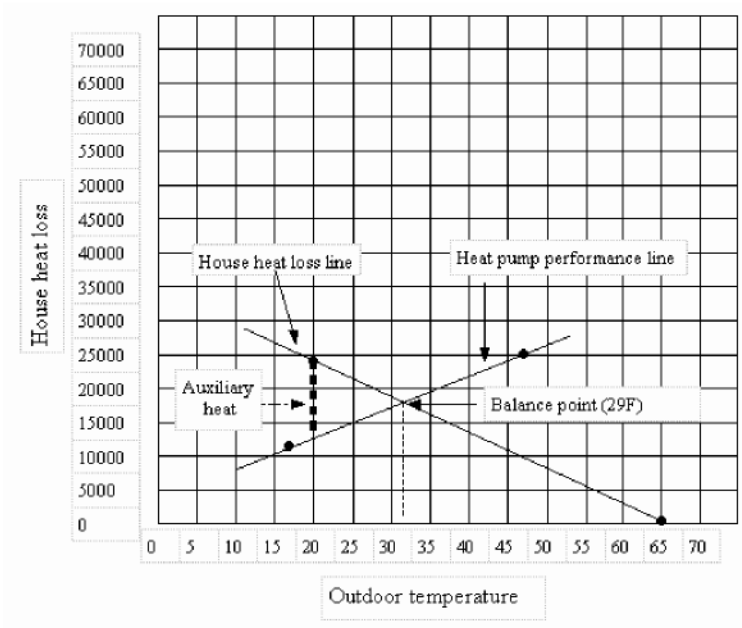
At 70 degree outdoor temperature our sample house will have 0 heat loss. At 20 degree outdoor temperature our house will have a 24,268 BTUH heat loss. Let's say we installed a 2-ton heat pump, 24,000 BTUH *(All right, the heat gain was only 10,979, so we're grossly over sizing the unit. If the house were notjust a sample, the load would be closer to 2 tons).* The heat pump manufacturer's specs indicate at 47 degrees the heat pump capacity is 25,000 BTUH and at 17 degrees its capacity is reduced to 12,000 BTUH. At some outdoor temperature the heat loss of the house and the capacity of the heat pump are going to be equal. This is called the **balance point.** If it gets any colder then the heat pump will need some help and auxiliary heat will be needed.

Below is a balance point chart. You can make one out of graph paper.

1. Place a dot at the intersection of the house heat loss BTUH and the design outdoor temperature (24,268 @ 20 degrees)
2. Place a dot at the intersection of 0 BTUH and 65 degree
3. Draw a line between them. This is the house heat loss line.
4. Place a dot at the intersection of the heat pump capacity (25,000 BTUH) @ 47 degrees and another dot at the intersection of the heat pump capacity (12,000 BTUH) @ 17.
5. Draw a line between them. This is the heat pump line.
6. Where the house heat loss line and heat pump line intersect is the balance point (31.5 degrees)
7. To determine the amount of auxiliary heat we need to know (1) what is the heat loss at the outdoor design temperature and (2) what is the heat pump capacity at that temperature. The difference must be made up with auxiliary heat. We know the heat loss is 24,368 BTUH. Looking at the heat pump line where it intersects 20 degrees appears to be about 12,500 BTUH; therefore the auxiliary heat should be 11,768 BTUH (24,268-12,500). If electric resistance heat were used as the auxiliary heat then we would divide the BTUHby 3413 to determine the KW (3413 BTU's = 1 KW).

11,768/3413 = 3.45 KW (auxiliary heat)

Balance Point Chart



Operating Cost

BIN METHOD (J7 only)

The most accurate method of calculating operating cost is the *bin method.* This method can be used for fossil fuels and heat pumps. The drawback is it is time consuming. The jist of the idea is to break up the heat loss into temperature bins of 5 or 10 degree increments. For example, turn to Table A4-1, find Raleigh, NC. Under the temperature bin 40-45 degree you will see 589 hours. If we knew the heat loss at this bin temperature we could use the formula:

FUEL BTU's = HEAT LOSS X HOURS

To get the heat loss we must determine the average temperature of the bin (40 + 45 = 85, 85/2 = 42.5 degrees). Now that we know the average bin temperature to be 42.5 we can determine the heat loss of our house at this temperature using the following method:

1. Determine the heat loss per degree temperature difference.

   Heat loss per degree = house heat loss / design temperature difference

   = 24,268/50

   = **485.36** btus /degree temp. diff.

2. Determine the temperature difference between the bin temperature and indoor design temperature.

Indoor design temp.	=	70
Bin average temp.	=	-42.5
Temp. diff.	=	**27.5**

3. Determine house heat loss at bin temperature (42.5)

Heat loss = TD X BTU's / degree temp. diff.

= 27.5 X 485.36

= 13,374 BTUH

Now that we know the heat loss at the bin temperature we can apply the basic formula:

FUEL BTU's=HEAT LOSS X HOURS

= 13,474 BTUH X 589 HOURS

= 7,936,186 BTU's

So far we have figured the fuel requirements for only one temperature bin. In order to get the total fuel requirements for the entire season we must go through steps 1-3 for each temperature bin between 20 degrees and 70 degrees (10 bins total), and then total up the BTU's for all bins.

To obtain the amount of fuel used:

FUEL=TOTAL OF BIN BTU's/(EFFICIENCY X BTU CONTENT OF FUEL)

The above example is for fossil fuels and electric furnaces only. Using the bin method for a heat pump requires knowing the coeffient of performance (COP), capacity and characteristics of the auxiliary heat for each bin. The calculation becomes quite encumbering. Appendix A-4 offers an explanation of the procedure as well as anywhere

USEFUL FORMULAS

HEAT LOSS

BTUH= U X TD X AREA

or

BTUH=HTM X AREA

SQUARE FEET = LENGTH X WIDTH

or

= LENGTH X HEIGHT

CUBIC FEET (VOLUME)= LENGTH X WIDTH X HEIGHT

or

= SQUARE FEET X CEILING HEIGHT

INFILTRATION BTUH (SENSIBLE) = CFM X 1.1 X TEMPERATURE DIFF.

To calculate CFM for infiltration

CFM = (Air changes per hour X Volume of house) / 60

INFILTRATION BTUH (LATENT) = CFM X .68 X GRAINS DIFF.

U-VALUE= 1/R

R-VALUE= 1/U

Important; U-values cannot be added to arrive at a new U value. U values must be converted to R values. Add the R values together, and then convert back to new U value.

Example:

An un-insulated wall has a U-value of .20. What is the new U-value if R-11 insulation is added?

1. Convert the U-value to R value: 1/.20 = R-5
2. Add: R-5+R-11=R-16
3. Convert new R value to **new U value:** 1/16 = **.0625**

HTM = U X TEMPERATURE DIFFERENCE

HTM (INFILTRATION) = **Sensible infiltration load / Total window and door area**

Guide to Manual N

The principles of Manual N are basically the same as those of Manual J. However, the internal loads, number of people and time of day have a significantly greater effect on commercial buildings than residences. To size equipment for commercial buildings we must know the **peak load.** While three o'clock in the afternoon might be the hottest part of the day, a business may experience a peak load at some other time of day. A restaurant, for example, will experience its peak between 12:00 PM and 1:30 PM, when the place is full of customers and all the cooking equipment is going full blast. Therefore it may be necessary to perform two load calculations, one at 3:00 PM and one at noon, to determine the true peak load.

As discussed in Manual J, **BTUH = U x TD x Area** or **BTUH = HTM x Area** (in case you've forgotten, HTM = U x TD). To make things a little easier Manual J has Tables 2, 3 & 4, listing all the HTM's at various temperature differences. Manual N does not offer this luxury. There are no HTM tables; therefore you must calculate the loads using the following formulas.

To determine the winter (heat loss) use the formula:

BTUH=U x TD x Area

To determine the summer (heat gain) use the formula:

BTUH = U x ETD x Area (for walls and ceilings)

BTUH = U x TD x Area (for doors, floors and partitions)

The **ETD** (equivalent temperature difference) takes into consideration the mass, color, direction it is facing, and, time of day. Before you jump out the window let's see how easy it is to calculate the heat gain through a wall.

A 10 ft. x 200 ft. south facing wall is constructed of hollow core, lightweight, 8" block with brick facing tight on block and no inside insulation or finish. What is the heat gain at 3:00 PM if we wish to design for a 20-degree temperature difference?

The formula is: BTUH = U x ETD x AREA

Step 1. Determine the U value.

Thumb through Tables 7 until you find a wall meeting the above description. Table 7H is the correct Table. The **U value is .253**

Step 2. **Determine the** ETD

The last column to the right in Table 7H indicates that this wall is an ETD group

A. Go to Table 8; under Group A, 3PM, South. You will see the **ETD is 17.**

Step 3. Determine the **Area**

Area = Length x height =10'x200'

= 2000 sq. ft.

Step 4. **Determine the heat gain**

BTUH=UxETDxArea

=.253X 17X2000

=8620BTUH

Note: Be sure to read notes at bottom of Table 8.

- Calculating the load for ceilings is done just like walls. Use Table 9 for ETD.

- For <u>floors, doors and partitions</u> use the **temperature difference x U** to calculate HTM, **not ETD** (equivalent temperature difference).

WINDOW LOADS

For **winter** load (heat loss) calculations use Table 5 to determine U value.

Example:

300 sq. ft. of double pane (Cl,T,Abs,R @1/4" gap), bare glass @ 45 degree temperature difference, located in Raleigh NC

Solution:

BTUH=UxTDxArea

a. Go to table 5 to find the U value for the described glass. The correct U-value is .62.
b. BTUH=.62x45x300
   = 8370

For **summer** load calculations on the same window, we must know the degree latitude, time of day, direction window is facing, amount of outside shading and type of inside shading.

Question?

If the above windows are facing east with inside horizontal blinds (medium color), 30% solar transmittance, and no outside shading, what is the solar gain at 12:00 PM?

Solution:

Solar gain = Adjusted solar heat gain factor (SHGF) x Area
We know the area equals 300 sq. ft.

To get the **adjusted solar heat gain factor** turn to tables 2A and 2B. At the top of Table 2A, it says, (Do not use for internally shaded glass). Our window is *internally* shaded by blinds, therefore, we must use table 2B.

The first thing we need to know is the latitude of Raleigh, NC. Find Raleigh, NC in Table 1 and look up the latitude (35 degrees). You will also see, in the last column, the daily range is M (medium). *If the glass had no internal shading you would need to know the daily range.*

Back to Table 2B, we will use the 40 degree column, as it lists larger SHGF's than the 32 degree column. Under 12 (12:00 PM) slide your finger down to E (east); you will see the **SHGF is 58.** Since the window has inside shading (blinds) we must apply a **shading factor.** Go to Table 3. Under the column labeled BLINDS (M), slide your finger down until you find a window matching our description. **.34 is the shading factor.**

Adjusted solar heat gain factor = SHGF x Shading Factor
=58 x.34
= 19.72

Therefore;

Solar heat gain = Adjusted solar heat gain factor x Area
= 19.72x300

=5916BTUH

Suppose the above glass has external shade screens. What would the SHGF be?

In Table 3 find SHADING FACTORS (SF) FOR EXTERNAL SHADE SCREENS. If the SF for the screen is .35, then the new SHGF would be:.

35x 19.72= 6.9

Hence the new solar gain would be: 6.9 x 300= 1170 BTUH

Note: glass area shaded by overhangs and porches is considered to be facing north. When obtaining the SHGF for shaded areas from Tables 2A or 2B use the N row. A good reference or calculating shaded and unshaded glass area is given below Table 4.

INFILTRATION AND VENTILATION

Loads presented by infiltration and ventilation are calculated the same as discussed in Guide to Manual J. Air changes per hour and door infiltration estimates are found in Tables 13A and 13B. Table 14 lists ventilation requirements (CFM per person) for various occupancies. Table 15 tells how many people per square foot should occupy a particular type building.

Question?

How many CFM of outside air is required for a 2500 square foot dining room? Answer:

Table 15 says, "Expect 14 people per sq. ft.".

Therefore: 2500 /14 = 179 people

Table 14 says "You need 10 CFM per person".

Therefore: 179 people x 10 CFM = 1790 CFM

To calculate the ventilation loads use the following formulas. If you need a further explanation of ventilation and infiltration, refer to pages 8 and 17 in Guide to Manual J.

$$BTUH\ (sensible) = CFM \times 1.1 \times TD$$

$$BTUH\ (latent) = CFM \times .68 \times Grains\ Difference$$

INTERNAL LOADS

Internal loads generally are not included in heat loss (winter) calculations, because most businesses are not operating in the middle of the night when the heating load is greatest. However, internal loads can have a significant effect on cooling equipment and must be accounted for.

A Manual J calculation calls for an appliance load of 1200 BTUH and a people load of 300 BTUH (sensible) and 230 BTUH (latent) per person. Obviously a commercial building could have any number of appliances, motors, people and lighting fixtures. Manual N offers Tables 10, 11, 11 A and 12 as a reference for calculating these loads.

In our dining room above, we determined 179 people would be having dinner.

Looking at Table 10, under Dining room we see that each person emits 255 BTUH (sensible) and 325 BTUH (latent). Therefore the heat gain would be:

Sensible 179 x 255 = 45,645 BTUH

Latent 179 x 325 = 58,179 BTUH
This is 8.5 tons just to satisfy the people load

If florescent lighting is installed at the rate of 3 watts per square foot, then 7500 watts (3 watts x 2500 sq, ft.) must be added to the load. See Table 11A for lighting gains.

7500 watts x 4.4 BTUH/watt = 30,750 BTUH

The kitchen may have a hooded gas griddle and a 15# gas deep fat fryer, a 1.5 hp mixer, and a refrigerator; for a total load of:

Item	Sensible	latent	Ref. Table
Gas griddle	3,600	0	12
Deep fat fryer	3,000	0	12
Mixer	3,390	0	11
Refrigerator	625	0	12
Total load	**10,616**	**0**	

HUMIDIFICATION LOADS (HEATING)

In the wintertime, especially in colder climates, we may wish to introduce moisture into the air in order to maintain a comfortable relative humidity (RE). Low RE causes dry skin and membranes and at 20% or below causes static electricity and drying out of furniture and building materials.

Generally, humidifiers add water to the air stream where it is evaporated and dumped into the occupied area. This evaporation process requires additional heat (BTUH). Tables 19A, 19B and 19C gives you the additional heating loads required to humidify a building per 100 CFM of outside flowing into the building.

For example:

Our dining room above requires 1790 CFM of outside air for ventilation. Using Table 19B, if the outdoor temperature is 20 degrees @ 80% RE and we wish to maintain indoor conditions at 72 degrees @ 35% RE, we would need to add 1975 BTUH to the heating plant for every 100 CFM of outdoor air.

1790/100 = 17.9
17.9 x 1975 = 35,355 BTUE
The daily water requirement would be:
17.9 x 5.3 = 95 gallons

DUCT SIZING IN THREE EASY STEPS A guide to Manual D

This section is based on the 1995 second edition of Manual D. However the principles, friction charts and fitting equivalent lengths are the same for all editions.

To size residential ductwork you only need to calculate three things.

1. What is the available static pressure?
2. What is the *adjusted static pressure* or *friction rate*
3. How many CFM per room is needed?

First let's discuss pressure. Air moving down a duct exerts two types of pressure; static pressure and velocity pressure. ***Static pressure*** is the pressure of the air pushing against the sides of the duct (this is the pressure that causes a balloon to increase in size). ***Velocity pressure*** is the impact pressure of the air caused by its movement (like a baseball, the faster its thrown the harder it hurts when you get hit). When we add both pressures together we get the *total pressure.* Luckily, for residential applications we only have to concern ourselves with static pressure.

The manufacturers of furnaces and air handlers print charts in their specifications indicating the amount of CFM to expect when connected to a duct system designed at various static pressures. For example, in figure 8-1 page 8-2 of Manual D (Blower Performance Chart) the manufacturer is saying "IF you want 1250 CFM then you must set the fan at medium speed and design an air distribution system that exerts exactly .49 inches of water column pressure (static pressure) against the fan. If the system is not designed to this static pressure and you end up with .14 in.wc then you will get 1400 CFM". Therefore, sizing a system using the specified static pressure is important in order to assure correct CFM.

Why is the correct CFM important? It affects the temperature of the air coming out of the furnace or air handler, which in turn, affects comfort and the life of the system. With air conditioners, CFM also effects humidity control (latent heat capacity). The following formula should be memorized:

CFM= BTUH / (1.1 X Temp Rise)

Suppose you have an 80,000 BTUH output furnace and you want 120 degree air coming out. The air entering will be room temperature (70 degrees), the air coming out will be 120 degrees; therefore, the temperature rise will be 50 degrees (120 – 70 = 50). The CFM required will be as follows:

CFM = 80,000 / (1.1 X 50)

= 80,000/55

= 1455

Let's get back to static pressure. If you will refer back to the blower performance chart on page 8-2, you'll see a footnote at the bottom saying the listed static pressures allow for a wet coil and air filter but not electric strips*. Electric strips, along with other components you might find in a duct system, such as dampers, registers and grills, electronic air cleaners, etc., add resistance to the airflow. This resistance is measured in *inches of water column (*" w.c.). The resistance for each component may be found in the manufacturer's specification sheets. Once we've identified all the components, and their resistance, to be included in the duct system, we will deduct the total resistance from the blower manufacture's static pressure requirement. The pressure that is left will be the

available static pressure for the duct system.

Example:

Manufactures specified SP for 1250 CFM	.49*with coil and filter
Other components: Electric strips	- .08
Registers	- .03
Grills	- .03
Dampers	-. 05
Available static pressure for duct system	.30” w.c.

- Always read footnotes to determine what components if any are included in blower performance charts. If, for example, the filter is not included in the manufacturer’s specs, the you would have to deduct it’s resistance along with the other components.

Now that we’ve figured the *available static pressure,* there’s one other adjustment to make. If you look at the bottom of the friction chart you will see a note saying, ***friction loss in inches of water per 100 feet***. If our duct system were exactly 100 feet in length, no further adjustment would be necessary. However, more likely than not, the duct system will be something other than 100 feet in length. Therefore, the available static pressure must be *adjusted* in order to deliver the required CFM.

If you were to connect a 1/2”, 50 ft. garden hose to a spigot, you might fill a 5-gallon bucket in 30 seconds (delivering 10 gallons per minute, GPM). If the 1/2” hose were 300 ft. long however, it might take 60 seconds to fill the bucket (delivering only 5 gallons per minute). The water pressure at the spigot is the same in both instances, but the longer hose is restricting the water flow due to greater *friction loss*. To get 10 GPM out of the longer hose we would have to either increase the pressure or increase the diameter of the hose. Air, like water, is a fluid, thus reacts the same way when forced down a conduit. When the pressure (fan speed) is constant our only option for controlling CFM is adjusting duct size

To determine the ***adjusted static pressure*** we use the formula:

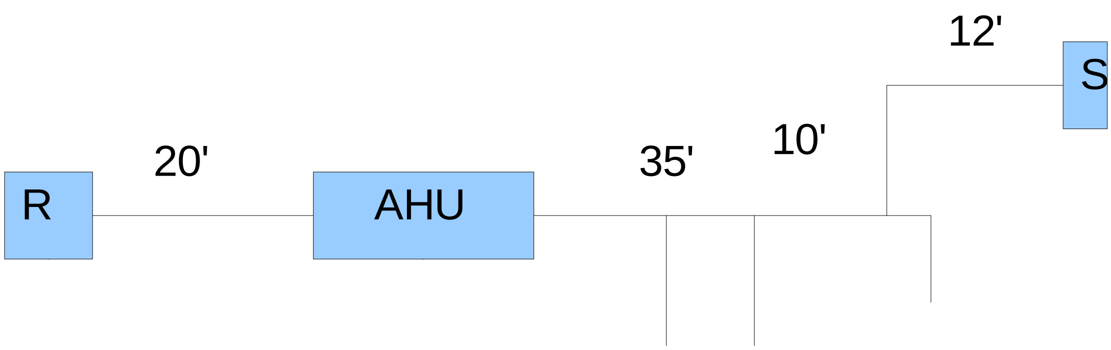
$$\text{ADJUSTED STATIC PRESSURE} = \frac{\text{AVAILABLE STATIC PRESSURE} \times 100}{\text{TOTAL EFFECTIVE LENGTH}}$$

In our example above, the *available static pressure* is .30” w. c. To determine the *total effective length* we must add together, the longest *measured length* and the total *equivalent lengths*.

TOTAL EFFECTIVE LENGTH = LONGEST MEASURED LENGTH + EQUIVALENT LENGTHS

Longest measured length

The longest measured length is the measured distance from the farthest return to the farthest supply outlet.



The above illustration shows the distances from the return to outlet F to be the **longest measured length, 77 ft. (20+35+10+12 = 77).**

Equivalent length

Each fitting, transition or turn in ductwork produces a resistance to air flow. This resistance is expressed in *equivalent feet.* Turn to page A3-12; look at figure 4-G. This is a typical boot used for a floor register. Beneath the figure is EL = 80. This means that the boot is equivalent to 80 ft. of straight duct. We must add the equivalent length of each component (in the longest measured run only, run F) together to determine the total equivalent length.

Example:

From the return to supply outlet F, are the following components:

	Equivalent lengths
Return air boot 6-F, page A3-1 8	25
Return transition at unit 5-C, page A3-13	40
Supply transition at unit 1 -D, page A3 -3	10
Supply reducer 12-H, page A3-26	20
Takeoff 2-A, page A3 -7	45*
Elbow group 8, page A3-20, 4 or 5 piece R/D = 1.0	20
Floor boot 4-G, page A3-12	80
Total equivalent length	**240 ft.**

*As air is dropped off at each branch, the remaining air in the trunk slows. Slower air is easier to turn, thus, the last run on a trunk will have a lower EL than the first.

Total Effective length

TOTAL EFFECTIVE LENGTH = MEASURED LENGTH + EQUIVALENT LENGTHS

= 77ft. + 240 ft.

= 317 ft.

Now we can determine the adjusted static pressure;

ADJUSTED STATIC PRESSURE = AVAILABLE STATIC PRESSURE X 100 / TOTAL EFFECTIVE LENGTH

= (.30 X 100)/ 317

= 30/317

= **.095**

.095 is the static pressure we will use to size the **entire duct system** whether using a friction chart or duct calculator.

Next, we need to know how many CFM to place in each room in order to achieve an even temperature. For illustration purposes, let's say the air handler in the example above (1250 CFM), is serving an 80,000 BTU}]I furnace. Supply outlets E and F are serving the living room how many CFM is needed in the living room and how many CFM must each outlet deliver?

There are two methods to calculate ROOM CFM either method will give the same results.

Method 1

First, we must perform a *room-by room* heat loss calculation to determine both, the living room and whole house load. If the whole house load is 58,000 BTU}]I and the living room load is 7900 BTU}]I then the percent of load represented by the living room is:

PERCENT OF LOAD PER ROOM = ROOM BTUH / WHOLE HOUSE BTUH

= 7900 / 58,000

= .136or13.6%

If the living room needs 13.6 % of the heat, then it makes sense it will need 13.6 % of the air coming out of the furnace. Therefore, 13.6% times 1250 CFM is 170 CFM.

ROOM CFM = ROOM LOAD PERCENT X FURNACE CFM

= .136 X 1250 CFM

= 170 CFM

Method 2

Manual D uses the following method. Either method produces the same answer. Calculate a cooling factor **(CF)** or heating factor **(HF)** then multiply the factor by each room load.

To get heating factor (HF)

$$\textbf{HEATING FACTOR(HF)} = \frac{\text{BLOWER CFM}}{\text{WHOLE HOUSE LOAD}}$$

$$= 1250 / 58{,}000$$

$$\mathbf{=.0215}$$

To get the room CFM

ROOM CFM = HF X ROOM HEAT LOAD

= .0215 X 7900 BTUH

= 170CFM

Since there are two outlets in the room, each will have to deliver 85 CFM (170/2).

Now that we know the *adjusted static pressure* (.095) and the room or outlet CFM (85) we can go to the duct calculator or friction chart and get the correct duct size. At point **A,** on the friction chart below, is the intersection of .095" w. c. and 85 CFM. One set of diagonal lines indicates the *round* duct size and the diagonal lines in the opposite direction indicate the velocity in feet per minute. These lines are circled. Looking at point A you will see the duct size falls between 5" and 6" and the velocity is about 500 FPM. Turn to manual D, page A1-2, Table 3-1. Since we are using round metal pipe, this is a **rigid branch supply duct,** the recommended velocity is 600 FPM - Max. - 900 FPM. Our velocity is only 500 FPM, therefore, if a 6" duct is chosen (do not fall back to the smaller duct), we will have a very quite duct run.

The duct runs for each of the other rooms are sized just like you sized the living room. <u>Continue to use the same adjusted static pressure of .095.</u> Calculate the ROOM CFM using either of the above methods, then go to the friction chart or duct calculator. REMEMBER TO CHECK VELOCITY

Sizing the supply and return ducts

You will notice on our duct drawing, there is a reduction about halfway down the supply. Once you determine the CFM required for each room you can calculate the amount of air each section must carry. Obviously the first section must carry all the air (1250 CFM) the second section (after the reducing transition), must carry enough CFM to feed the last 7 runs; let's say 715 CFM. Size the first section of duct at point **B** (1250 CFM @ .095" w.c.). Check the duct size (16"), check the velocity (about 980 FPM); Table 3-1 says maximum velocity is 900 FPM. What do you do? Slide the point to the left along the 1250 CFM line until you fall below 900 FPM, then, select the duct size indicated (18"). The last section carries 715 CFM. Locate 715 CFM @ .095 on the friction chart and check duct size and velocity (14"duct @ about 850 FPM. According to Table 3-1, a 14' duct is allowable. The return trunk is sized just like the supply;

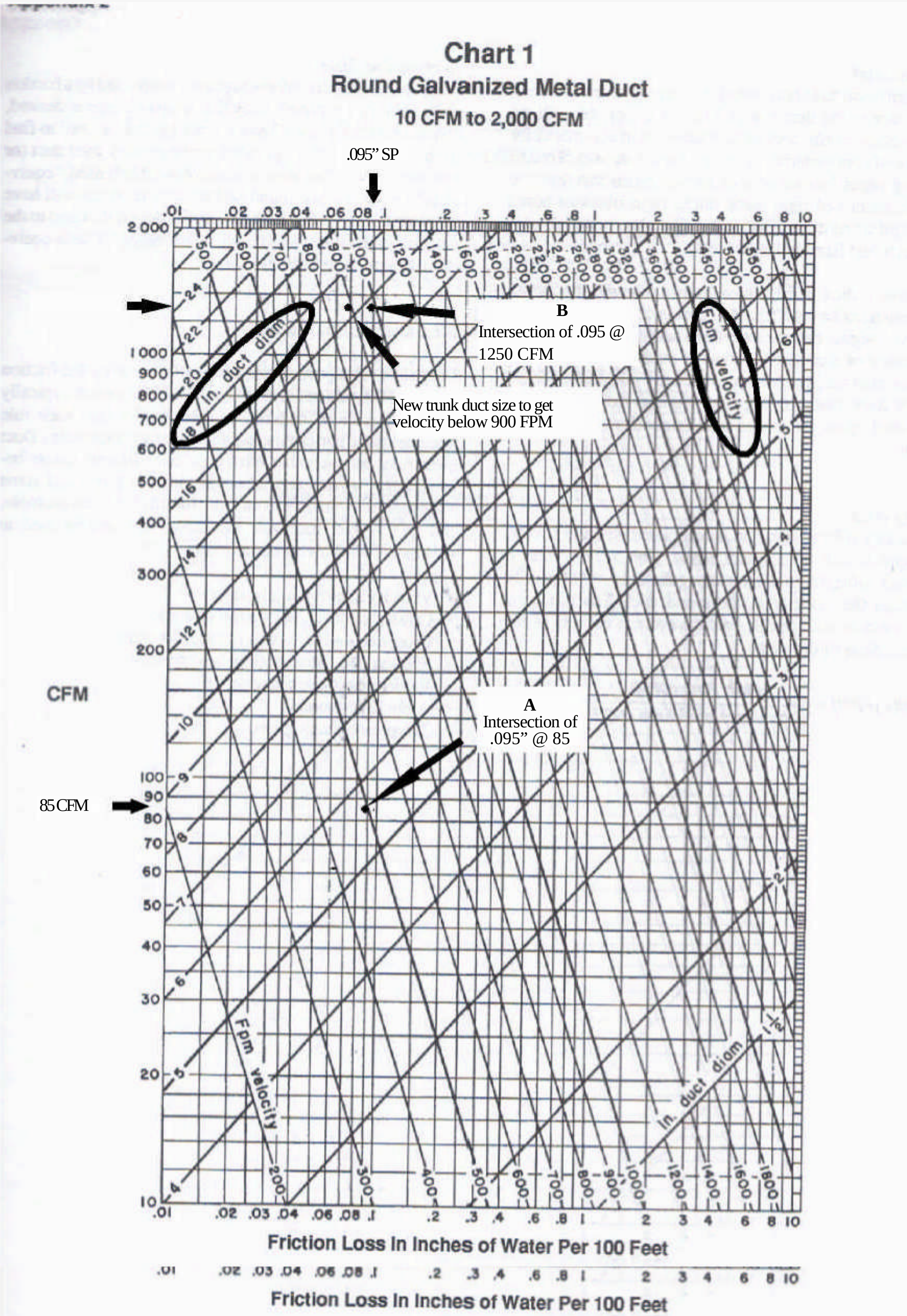


Chart 1
Round Galvanized Metal Duct
10 CFM to 2,000 CFM
.095" SP
B
Intersection of .095 @ 1250 CFM
New trunk duct size to get velocity below 900 FPM
A
Intersection of .095" @ 85
85 CFM
CFM
In. duct diam
Fpm velocity
Friction Loss In Inches of Water Per 100 Feet

A few notes on manual D

1. Be sure to use the correct friction chart. There is a different chart for each type of duct material; metal, lined, flex, etc.
2. When converting round duct sizes to rectangular duct sizes **use Chart 9.** Do not attempt to use pie-r-square. Although the area may be the same, the pressure drop is greater in rectangular duct because the air is exposed to more wall area per linear ft.
3. Flexible duct bends. Use group 11, page A3-25, to determine the equivalent length of bends in flex duct. Study example in bottom left box.
4. When sizing ductwork for **zoning,** a room-by-room load calculation must be performed using the **peak load** method as prescribed in Manual J eighth edition. Trunk lines and runs serving each zone must be sized according to each zone's peak load. The main trunk, between the air handler and the first zone damper may be sized using the houses average load. Generally, the greatest differences between peak and average loads occur with the heat gain calculation, therefore, in most cases, you would use heat gain loads for sizing the duct system.

As a quick example, let's suppose we install a 31/2-ton, 1400 CFM air conditioner in a house having a total sensible heat gain of 33,000 BTU}]I using Manual J seventh edition (seventh edition uses average method). The load for a room facing east is 5500 BTU}]I and a room facing west is 4200 BTU}]I. In reality, at 3:00 in the afternoon the room facing east may only require 2300 BTU}]I because the sun is on the west side of the house at that time. Meanwhile the sunbathed west facing room may require 7200 BTU}]I. A zoned system must be designed to deliver this peak load (7200 BTU}]I) to the room. The room CFM, therefore would be:

$$\textbf{COOLING FACTOR (CF)} = \frac{\textbf{BLOWER CFM}}{\textbf{WHOLE HOUSE LOAD}}$$

$$= \frac{1400}{33,000}$$

$$= \mathbf{.042}$$

ROOM CFM = CF X ROOM COOLING LOAD

=. 042X 7200

=302CFM

Once the room CFM is calculated, use the same methods described above to determine the *adjusted static pressure* then size the duct accordingly.

Bypass duct

A duct system with two or more zones should have a bypass duct located between the supply and return trunks, thus enabling a passageway for excess air to be returned to the blower when one or more zones are closed. The duct should be located on the supply just before the first zone damper. The bypass duct will also include a damper, which is controlled to open as the static pressure increases.

Suppose the above example house has three zones. A **peak load** calculation results in the following CFM requirements: Zone A-450 CFM, Zone B-575 CFM and Zone C-660 CFM (total-1685 CFM). To size the bypass duct, subtract the smallest zone CFM from the blower CFM and size the duct using the resulting CFM and system adjusted static pressure.

Blower CFM	1400
Smallest zone (Zone A)	-450
Bypass duct CFM	950

5. Air flow formulas

BTU=CFM X 1.1 X TD

CFM= BTU/(TD X 1.1)

TD= BTU/(CFM X 1.1)

If you wanted to know the temperature rise through a furnace which formula above would you use?

Answer: $TD = \frac{BTU}{CFM X 1.1}$

If the furnace is rated at 80,000 BTUH output @ 1400 CFM, what is the temperature rise?

Answer: $TD = \frac{BTU}{CFM X 1.1}$

= 80,000 / (1400x 1.1)

= 52 degrees

If you have a 15 KW electric furnace with a 42-degree temperature rise, what is the CFM?

Answer: CFM = BTU/ (TD x 1.1)

First convert KW to BTU - 15KW X 3413 BTU per KW = 51,195 BTU's

$$= \frac{51,159}{42 \times 1.1}$$

= 1107 CFM

Velocity (feet per minute)

FPM= CFM/AREA note: area is in square feet, 1 Sq. Ft. = 144 Sq. Ft.

What is the velocity (FPM) of air in a duct measuring 12” x 30” moving 1400 CFM?

$$\text{Answer: FPM} = \frac{\text{CFM}}{\text{AREA}}$$

First convert square inches to square feet. 12” X 30” = 360 Sq. In

Therefore: 360/144 = 2.5 Sq. Ft.

$$\text{FPM} = \frac{1400}{2.5}$$

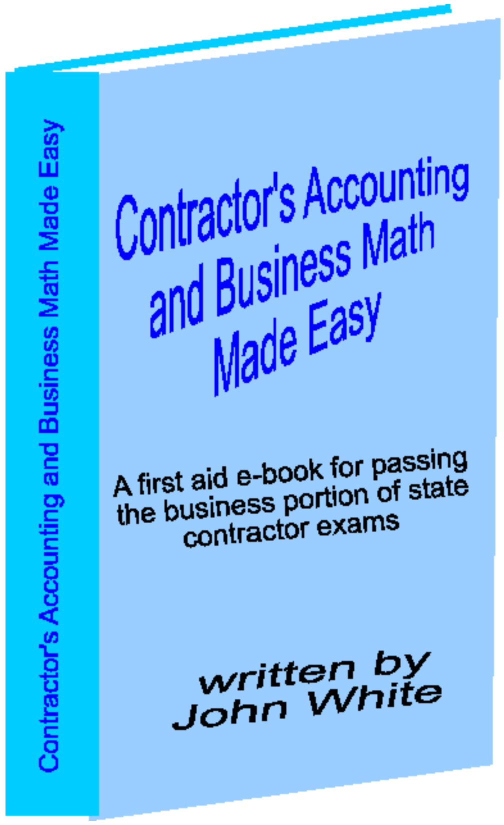
= **560 FPM**

If the velocity in the above duct is 650 FPM; what is the CFM?

Answer: CFM = FPM X AREA

= 6 5 0 X 2 . 5

= **1625 CFM**



ENERGY MARKETING SERVICES

374 CATTLELOT LANE
BELHAVEN, NC 27810
252-341-5028

www.johnrwhite.net

Accounting and Business Math Made Easy

One of the most dreaded and toughest courses in school is accounting. Accounting ranks up there with chemistry and physics. Fact is, if you can get your thought process started off right, then, accounting becomes not only easy, it becomes completely logical. Once you see the light you'll wonder why anyone would find accounting difficult. This little e-book is going to start you from the very beginning. So let's get started

CASH

Cash is where accounting begins and ends. You debit cash when you receive it and you credit cash when you spend it. All other accounting entries depend on their relationship to CASH. Allow me give you an example; Joey has just started a yo-yo company with $2000 dollars. His accounting entry will be $2000 in the debit column (left side) of his cash account. One rule of accounting says, for every debit there must be a credit (right column) and vice versa, therefore, if he borrowed the money to get started he will have to credit **accounts payable.** If he had the money, perhaps from savings he would credit **owner's equity. Nevertheless, he must credit something.** For the purpose of our discussion we will say he borrowed the money, therefore he will credit accounts payable.

At this point if Joey were to prepare a **balance sheet** (a statement listing assets, liabilities and owner's equity) he would show zero equity, his total **assets** are $2000 cash and his total **liabilities** are $2000 accounts payable. **Assets minus liabilities equal owner's equity.** The only way his equity will change is if he does some business. If he does things right he will make a **profit,** if not, he will suffer a **loss.** Owner's equity can be either a plus or minus figure.

Assets are items you own. **Liabilities** are items you owe.

Remember, when you receive cash you debit the cash account and always credit the item you received cash for. When you spend cash you credit the cash account and debit the item you paid for.

How does Joey keep up with his **daily** sales and expenses? In a **journa**l. Joey has two journals; a cash receipts journal and a cash disbursement journal. A journal is a book with a bunch of columns for listing accounts. For example, when he pays the light bill he uses the cash disbursement journal. He will enter the amount paid in the credit side under the cash column and the debit side under the utility column.

Joey rents a building, purchases fire insurance, installs a telephone, buys an ad in a trade magazine, gets the lights turned on and hires a secretary/bookkeeper. All these **expenses** are necessary to run his business. Because these expenses are necessary whether or not he does any business they are called **overhead expenses.**

Expenses are all costs associated with doing business. If the expense increases or decreases directly with sales then it is a **direct** or **variable expense.** If the expense remains constant regardless of sales volume then it is a **fixed** or **overhead** expense.

How does Joey make his accounting entries for these initial expenses? Up until now he has only two accounts, cash and accounts payable. Now he has incurred new expenses, each of which will require a separate account. Let's see how they will be set up.

Rent- The rent is $150 per month with a $150 security deposit. This transaction requires two accounts; (1) rent expense and (2) security deposit. When Joey pay's the total $300 he will **credit** cash (he's taking money out of the cash account) and **debit** rent expense for $150 and security deposit for $150. Why two separate accounts? Because the **rent is an expense** but the **security deposit is an asset;** it is your money; it's just been moved into the landlords account

Insurance- Joey's insurance cost is $360 per year and he must pay for it up front. He will again credit his cash account for $360 because he had to write the check. Again he must set up two insurance accounts to debit. One account is called **insurance expense** the other is called **prepaid insurance.** What's the difference? When Joey first buys the insurance he does not use it all at one time, he uses it at the rate of $30 per month. Therefore his initial entry would be a $360 debt to prepaid insurance, which is an asset account. Insurance expense will remain at $0 At the end of the month he will credit prepaid insurance for $30 and debit insurance expense for $30.

After four months his total insurance expense will be $120 and his prepaid insurance (asset) will be reduced to a balance of $240.

Items such as stamps and stationary, although technically can be prepaid assets are considered expenses and do not require prepaid accounts.

Lights and telephone- If, Joey has to pay a deposit to have these items turned on then the deposit will be a credit to cash and a debit to security deposit. Remember security deposit is an asset not an expense. At the end of the month when the first bills come in, the transaction will be a credit to cash and a debit to lights and telephone expense respectively.

Advertising- The ad Joey bought costs $480 and the ad agency is offering 30 day's credit. Since no cash has been exchanged yet, the entry will not affect the cash account, however the advertising expense has been incurred. Therefore, advertising expense must be debited and as stated earlier, for every debit there must be a credit. So what will we credit? **Accounts payable** (a liability) is the answer. At the end of the month Joey will pay the ad bill, cash will be credited and accounts payable will be debited, leaving a zero balance. Advertising expense will be left untouched with a $480 debit balance

Secretary/bookkeeper- this person is an administrative expense, also part of the company overhead. If the secretary is paid $400, cash is credited for $400 and office salaries are debited for $400.

As you may see by now, anytime cash is spent it is credited and, whatever the cash is paying for, is debited. The debited account can be either an expense or an asset.

Let's see what happens when Joey starts doing some business. Joey receives his first order from Acme Toys for $200 worth of yo-yos. Did he receive cash? No, it's just an order. The only thing he can do with an order is make a note that it needs to be filled but there is no accounting entry. Joey does, however, need to buy some wood, strings, clue and a lathe to produce the yo-yos. The bank finances a lathe for $10,000 at $300 per month he charges $75 worth of wood and clue and pays $10 cash for string. What do his entries look like?

The day the lathe is delivered he creates an asset account called lathe and debits it for $10,000. Since he has not yet made any payments to the bank he will credit notes payable account (this is an account payable, but over time) for $10,000. At the end of the month he will make a payment, which must be split between interest and principal. Lets say the first payment of $300 contained $75 interest. Therefore his entry will be $300 credit to cash, $75 debit to interest expense and $225 debit to notes payable.

The lathe is an asset. Because it is a relatively expensive item with a relatively long service life it is **capitalized,** which means it may be depreciated over its useful life. Smaller, less expensive tools may be treated as expenses.

The $75 he charged for wood and glue will be entered as a debit to materials account and a credit to accounts payable and the $10 for string will be a debit to materials account and a credit to cash.

A few days later Joey has produced the order and shipped them out to Acme Toys. The secretary makes out an invoice (bill) and sends it to Acme. The bookkeeper enters a

$200 debit in the accounts receivable account and credits sales (revenue). When Acme pays the bill, Joey's bookkeeper will debit cash and credit accounts receivables. The sales account will remain untouched as a sale is a sale, and a sale is made whether it is paid for or not. Below are sample journal entries of Joey's business.

GENERAL JOURNAL

date	description	debit	credit
2/5/2007	cash	2000	
	accounts payable (loan from Uncle Bob)		2000
2/7/2007	cash	150	150
	rent expense		
2/10/2007	cash		360
	prepaid insurance	360	
2/10/2007	cash		50
	utility deposit	50	
2/10/2007	cash		100
	telephone deposit	100	
12/12/2007	account payable		480
	advertising expense	480	
12/12/2007	cash		400
	salaries	400	
12/20/2007	cash	10,000	
	notes payable (loan from ABC bank)		10,000
12/20/2007	cash		10,000
	equipment (lathe)	10,000	
2/24/2007	accounts receivable (Acme Toys)	200	
	sales		200
3/1/2007	cash		100
	account payable (Uncle Bob)	90	
	interest expense	10	
3/1/2007	cash		300
	notes payable (ABC Bank)	225	
	interest expense	75	
3/10/2007	cash	200	
	accounts receivable (Acme Toys)		200

After a few months in business Joey is beginning to realize that he can't keep up with who owes him and whom he owes. The bookkeeper suggests he start keeping ledgers. Ledgers are books that contain a page (ledger sheet) for each individual creditor **(accounts payable ledger)** and each individual customer **(accounts receivable ledger).** At the end of each day, or with some businesses, each week or month, the bookkeeper will transfer the information in the journal to a ledger. **Accounts receivable** is an account with a running total of **all** money owed to Joey. It does not contain individual customer balances. The **accounts receivable ledger** shows the amount owed by each customer. Likewise **accounts payable** is an account showing **all** the money Joey owes. The **accounts payable ledger** shows balances of each creditor.

Now that I've attempted to help you understand the basic principles of accounting you may still be saying "Huh! What did he say?'

If you noticed, the decision of whether an item should be debited or credited is determined by whether Joey (1) has received cash (2) will receive cash (3) has paid cash or (4) will pay cash

When cash is received- debit cash, credit sales (revenue)

When you will receive cash- debit accounts receivable, credit sales (revenue)

When a customer pays on his account- debit cash, credit accounts receivable

When you pay cash- credit cash, debit the appropriate expense or asset account

When you (charge) will pay cash- credit accounts payable, debit the appropriate expense or asset account.

Once you have paid cash (on charge acct)- credit cash, debit accounts payable.

Where I live we have a lot of crabbers. A typical one-man crab company would have a balance sheet that looks like this (keep in mind a great big, multi-million dollar corporation will have a balance sheet and accounting system based on the same principals, only the dollars and the number of accounts will be greater).

JACKS CRAB OPERATION
BALANCE SHEET
December 31, 2007

Assets		
Current assets		
Cash		$ 580
Inventory (crabs)		95
Accounts receivable		230
Total current assets		905
Other assets		
Prepaid insurance		180
230 crab pots		5,750
24 foot Carolina skiff		39,280
Depreciation		(8750)
8 months prepaid slip rent		1120
Total assets		$38,485
Liabilities and owner's equity		
Current liabilities		
Accounts payable		$ 125
Total current liabilities		125
Other liabilities		
Note on boat		21,200
Note on crab pots		1480
Total liabilities		$22,805
Owner's equity	$15,680	
Total liabilities and owner's equity	$38,485	

A balance sheet tells how much you own (assets), how much you owe (liabilities) and how much your worth (owners equity). When borrowing money, the lender is most interested in your current asset to current liability ratio. According to Jack's balance sheet, his ratio is 7.24:1, which is very good ($905/$ 125). If this ratio ever becomes less than 1:1 it might be time to bail out, as Jack will not be able to meet his current obligations.

The income statement would look like this.

JACKS CRAB OPERATION
INCOME STATEMENT
Dec. 31, 2007

		$32,300	
Sales			100%
Direct costs	$2250		
Fuel and oil	900		
Bait	480		
Misc. supplies	3630		11.2%
Cost of goods sold			
Overhead		3400	
Slip rent	700		
Depreciation	8900		
Insurance	320		
Licenses	125		
Repairs	1670		
Interest	1920		
Total overhead	13,635		42.2%
Total costs and overhead	17,265		53.5%
Income from operations	14,035		43.5%
Other income			
Gain on sale of boat			
Income before taxes	17,435		54%
Income taxes	4360		
Net income			
13,075	40.5%		

Notice the percentages to the right. Each represents a percentage of total sales (revenue). For example, overhead equals 42.2% of sales ($13635/$32,300). When we talk about percentages in business they are generally expressed as *percent of sales*. When a businessperson says his gross profit is 28%, he means 28% of total sales. Therefore, if his total sales were $150,000, then his gross profit would be $42,000 ($150,000 x .28).

Using data taken from the balance sheet and income statement, a number of other financial ratios can be determined. Two important ratios are:

Debt-to-Equity

= Total liabilities/owner's equity

= $22,805/$ 15,680

= 1.45 (this means Jack owes 1.45 times more than he is worth)

Return-on-Investment

= Net income/assets

=$13,075/$3 8,485

= .40 or 40% (this tells Jack he is making the equivalent to 40% interest on his investment)

How to price ajob and stay in business

This is perhaps the most important section of this book. If you do not make a profit you do not stay in business. Before we talk about profit, let's talk about pricing. The price of a product is dictated, in a capitalistic world, by supply and demand. When supply is high and demand is low the price is low and when the supply is low and demand is high the price is high. If you're fortunate enough to offer a product with low supply and high demand then you may charge whatever the market will bare. If, however, your product falls into the mature product category where demand is high or good and supply is high or good then your price may very well be dictated not by you but by the going market price. Unfortunately, in a mature market there are competitors whom will offer their goods at prices below their costs in order to increase sales. Eventually their business fails, but not before establishing a new low benchmark for your products price.

Industries dominated by small businesses are the most susceptible failure due to soft prices because most small business owners do not understand or will not accept the fact that there is a break even point in pricing and when that point is reached it's time to reevaluate your business strategy. Large companies, Proctor and Gamble for example, are vying for market share just like the little guy's, the difference is, they have an army of cost accountants that are constantly keeping an eye on the break even point. If they get too close to the break-even point with price they will use another marketing gimmick to gain share such as change packaging or make it *new and improved*, but they will not lower the price below break even. P&G's competitors are just as business savvy; they also know that products cannot be sold below cost and still stay in business. Therefore the large companies rarely are put out of business because of price wars.

So, how do you price ajob or product in a competitive market?

Know your product cost

In Joey's yo-yo business let's say he has $1.00 in labor and material per yo-yo.

Know your overhead %

Joey's income statement from last year showed 15% overhead

Know what % profit will make you happy

For our example, Joey feels like 12% is the minimum profit he will accept

The calculation

What does the sales price have to be to cover Joey's overhead and profit? Solution:

1. He knows the material and labor cost per yo-yo is $1.00
2. Joey's overhead + profit = 27%

3. Therefore, he must mark-up his yo-yo 27% in order to cover cost and overhead.

Most readers (99%) would say, “Well, this is simple, just multiply $1.00 x .27 then add the answer to $1.00 or simply multiply $1.00 x 127%, either way the sales price will be $1.27”. **WRONG!** Don’t believe me? Ok, then give me a 25% discount, after all your still making 2%. Try it; see what happens. If your math is correct you will be selling the yo-yo for about $.95 which means you’re going to lose about a nickel instead of making 2 cents. Why? Because the sale price was figured as a percentage of *cost* ($1.00) not sales

Remember all financial percentages used in business are percentages of sales not cost.

The correct method

The following is the correct method for figuring a sales price. We are not going to go into the where and why, just remember this for the exam.

Always start off with 100%
Deduct the percent you need to cover overhead and profit (27%)
This leaves 73% (100% - 27% = 73%)
Divide the cost ($1.00) by 73%
1.00/.73 = **$1.37 sales price**

Joey will sell his yo-yos for $1.37 each. If the market will not bear this price then he needs to find something else to do for a living, unless he swallows his pride and takes a smaller percentage of profit.

The above formula should be used to figure all jobs. For example if you pay $1750 for a heat pump, $850 for ductwork, $1200 labor, and $50 for a permit. Your overhead is 20% and you wish to make 25% profit what price would you sell the job for.

1.00- .20- .25=.55

Total cost of job = $3850

Sales price = $3850/.55

Sales price = **$7000**

Let’s have some more fun with numbers and percentages now that you’re getting the hang of it.

What would your annual sales have to be if you are selling a product with a 15% profit and you need to make $75,000?

Solution: $\frac{\$75,000}{.15} = \$500,000$

Suppose you raise your price 5% and make 20% profit?

Solution $\frac{\$75{,}000}{.20}$

$= \$375{,}000$

Moral of the story: Raise your price a little bit and do a whole lot less work. Lower your price a little bit and do a whole lot more work.

Payroll

Below are some examples and explanations of payroll calculations. For this discussion I will use Willie as my payroll guinea pig.

Willie earns $12.00 per hour, is married, claims 3 withholding allowances and is paid weekly. I will use a 2003 Circular E (federal income tax tables). Other years work the same way; only the numbers have changed.

Before doing the math, we must understand the federal government's Fair Labor Standards Act. This act mandates a minimum wage and dictates when overtime must be paid.

Basically, overtime must be paid at a rate of 1 1/2 times the regular hourly wage if the employee works over 40 hours in any one week. Willy's overtime rate will be $18.00/hour. (12.00 X 1.5 = 18.00)

If Willie works 40 hours, his pay will be $480 ($12 x 40= $480)

If Willie works 48 hours, his pay will be $624 ($12 x 40 plus $18 x 8 = $624)

If Willie puts in 40 hours during Thanksgiving week and works on Thanksgiving Day, a paid holiday, he will be paid for 48 hours, but only straight time; $576 ($12 x 48= $576)

An employee must physically work over 40 hours per week to get overtime pay. If Willie works a 12-hour day he will only be paid straight time. The law has no restriction on the number of hours worked per day, just per week. **A week is 168 consecutive hours.**

If Willie takes a day off this week to go fishing (works 32 hours) and makes his time up next week (works 48 hours) then he must be paid 8 hours overtime. The law says an employee cannot work more than 40 per week, period, without paying overtime.

MARRIED Persons—**WEEKLY** Payroll Period

(For Wages Paid in 2003)

If the wages are–		And the number of withholding allowances claimed is—										
At least	But less than	0	1	2	3	4	5	6	7	8	9	10
		The amount of income tax to be withheld is—										
$0	$130	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
130	135	1	0	0	0	0	0	0	0	0	0	0
135	140	1	0	0	0	0	0	0	0	0	0	0
140	145	2	0	0	0	0	0	0	0	0	0	0
145	150	2	0	0	0	0	0	0	0	0	0	0
150	155	3	0	0	0	0	0	0	0	0	0	0
155	160	3	0	0	0	0	0	0	0	0	0	0
160	165	4	0	0	0	0	0	0	0	0	0	0
165	170	4	0	0	0	0	0	0	0	0	0	0
170	175	5	0	0	0	0	0	0	0	0	0	0
175	180	5	0	0	0	0	0	0	0	0	0	0
180	185	6	0	0	0	0	0	0	0	0	0	0
185	190	6	0	0	0	0	0	0	0	0	0	0
190	195	7	1	0	0	0	0	0	0	0	0	0
195	200	7	1	0	0	0	0	0	0	0	0	0
200	210	8	2	0	0	0	0	0	0	0	0	0
210	220	9	3	0	0	0	0	0	0	0	0	0
220	230	10	4	0	0	0	0	0	0	0	0	0
230	240	11	5	0	0	0	0	0	0	0	0	0
240	250	12	6	0	0	0	0	0	0	0	0	0
250	260	13	7	1	0	0	0	0	0	0	0	0
260	270	14	8	2	0	0	0	0	0	0	0	0
270	280	15	9	3	0	0	0	0	0	0	0	0
280	290	16	10	4	0	0	0	0	0	0	0	0
290	300	17	11	5	0	0	0	0	0	0	0	0
300	310	18	12	6	1	0	0	0	0	0	0	0
310	320	19	13	7	2	0	0	0	0	0	0	0
320	330	20	14	8	3	0	0	0	0	0	0	0
330	340	21	15	9	4	0	0	0	0	0	0	0
340	350	22	16	10	5	0	0	0	0	0	0	0
350	360	23	17	11	6	0	0	0	0	0	0	0
360	370	25	18	12	7	1	0	0	0	0	0	0
370	380	26	19	13	8	2	0	0	0	0	0	0
380	390	28	20	14	9	3	0	0	0	0	0	0
390	400	29	21	15	10	4	0	0	0	0	0	0
400	410	31	22	16	11	5	0	0	0	0	0	0
410	420	32	23	17	12	6	0	0	0	0	0	0
420	430	34	25	18	13	7	1	0	0	0	0	0
430	440	35	26	19	14	8	2	0	0	0	0	0
440	450	37	28	20	15	9	3	0	0	0	0	0
450	460	38	29	21	16	10	4	0	0	0	0	0
460	470	40	31	22	17	11	5	0	0	0	0	0
470	480	41	32	24	18	12	6	0	0	0	0	0
480	490	43	34	25	19	13	7	1	0	0	0	0
490	500	44	35	27	20	14	8	2	0	0	0	0
500	510	46	37	28	21	15	9	3	0	0	0	0
510	520	47	38	30	22	16	10	4	0	0	0	0
520	530	49	40	31	23	17	11	5	0	0	0	0
530	540	50	41	33	24	18	12	6	0	0	0	0
540	550	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Circular E

Three federal deductions are taken out of Willie's check; income tax, social security, and Medicare. Income tax is computed using the above schedule in Circular E. Social security is calculated as 6.2% of income. Once Willie earns $94,200 for the year, he will no longer have to pay social security (2006 figures). Medicare is calculated as 1.45% of his income with no limit. In addition to federal taxes, state income taxes are also deducted (check with your state for tax rate).

Example:

Willie works 42 hours for the week. The state income tax rate is 7%. What is his take home pay?

40 hours regular time X $12.00 = $480

2 hours overtime X $18.00 = $ 36

Total pay = $516

Federal income tax – Using the circular E schedule above, locate the column at the top labeled 3 allowances, go down the column until you reach the row 5 10-520 and you will see **$22** as the tax amount of tax to withhold.

Social security – Obviously, Willie has not made $94,200 this year, therefore his social security will be 6.2% of $516.

(Social security)	.062 X $516 =	$31.99
(Medicare)	.0145X$516=	7.48
(Federal tax)	see circular E	22.00
(Statetax)	.07x$516=	36.12

All four withholdings add up to $97.59, which is deducted from his check.

Weeklypay	$516.00
Total withholdings	- 97.59
Take home pay	**$418.41**

There are certain taxes related to the employee's income that **the employer must pay.** These include:

Social security – The social security rate is actually 12.4%. The employee pays half and the **employer pays half** (6.2% each)

Medicare – The Medicare rate is actually 2.9%. The employee pays half and the **employer pays half** (1.45% each).

Federal unemployment tax (FUTA) - .8% of the first $7000 of employee's salary. This is paid once a year by the employer and may not be deducted from the employee's pay. If FUTA is not paid on time then the rate is 6.2%

State unemployment tax – This varies state-by-state and must be paid by the employer and may not be deducted from the employee's salary.

Where and when does the employer deposit the funds withheld from employees?

FICA funds (social security and Medicare) and federal income taxes withheld must be deposited in a **federal depository bank or Electronic Federal Tax Payment system (EFTPS).** Most major banks are federal depository banks. The frequency at witch the funds must be deposited is based on the total amounts withheld from all employees. Circular E gives instructions on when deposits must be made.

Unemployment taxes are sent to their respective agency.

Untimely payments are subject to penalties; some may be substantial. These penalties are outlined in Circular E.

A **payroll journal** should be maintained to account for the total withholding moneys and a **payroll ledger** should be maintained to keep a record of each employee's wages and withholdings.

Administration and Laws

This manual does not attempt to discuss or explain administrative rules, state or federal laws, as the reference material is pretty much cut and dry. You should be able to look up the answers during the test.

One caution; take note of the current names of the insurance commissioner, council and committee members found at the beginning of the *Administrative Code.*

Questions regarding **state** laws will be from the Boards *Laws and Rules* book, the administrative code and the first chapter of all other codebooks. Question regarding **federal laws and state laws** will be found in the *Business Project Management for Contractors* book.

International Residential Building Code

Almost all test questions pertaining to this code will come from Section N1 103, paragraphs N1 1 03. 1, N1 1 03.2 and N1 1 03.3 and Table N1 1 03. 1. The sections state Residential heat pump control requirements, duct insulation requirements and a table of minimum efficiency requirements. **Do not use insulation and control requirements stated in the Energy Code for residential applications. The Energy Code is for commercial applications.**

What is the minimum SEER rating for a packaged air conditioner?

The answer is not 13 or 10, look it up in Table N1 103.1, Residential Building Code.

INTERNATIONAL ENERGY CODE

Almost all questions pertaining to this code will come from Section 503. The requirements of this code are for **commercial** applications. **Residential** controls, duct and pipe insulation requirements are in the *NC residential building code.*

Things to look out for:

1. Read paragraph 503.3.2.2. These requirements are for commercial installations only
2. There are two tables labeled Minimum Pipe Insulation. **Use table 503.3.3.3** to determine R-value requirements **for ductwork.** The TD is >40.

INTERNATIONAL MECHANICAL CODE

Attempting to memorize the code at this time could test your sanity, however you must read and highlight it. When reading the code, you may not remember the minimum size screen needed to protect outdoor intake openings or how far off the ground a duct should be, but you will know there is a code requirement. Only time and experience will make you an authority. You will be supplied plenty of time

Most items in the Mechanical Code are self-explanatory. Below we will discuss a few things that may give you trouble.

Outdoor ventilation

All buildings, including residences require a certain amount of outdoor ventilation, measured in CFM. Turn to Table 403.3. Locate *conference rooms* in the Office category. To the right you will see the estimated maximum occupancy of 50 people per 1000 square feet, and the required CFM of outdoor air per person to be 20.

A question might be: How many outdoor CFM are required to ventilate a 1500 sq. ft. office conference room?

Solution: The code says figure 50 people per 1000 sq. ft., we have 1500 sq. ft. Therefore, the room will hold 1 1/2 times 50, or 75 people total.

1500/1000= 1.5

1.5 X 50 people=**75**

20 CFM is required for each person.

20 X 75=**1500CFM**

Domestic clothes dryers (504.6)

According to the requirements of the code is a 30 ft. rigid dry vent will two 90-degree bends allowed?

Answer: No. The section states, the maximum length cannot exceed 45 ft., less 10 ft. for each 90 degree bend (+45-10-10 = 25ft.). 25 ft. is the longest the vent is allowed.

Medium-duty cooking appliance exhaust hood (507.13.3)

How many CFM is required for a 4’ X 6’ island hood? Hood is 6’ long.

Answer: 3000 CFM

A single island canopy requires 500 CFM per linear foot. The hood is 6 linear feet, thus 6’ X 500 CFM = 3000CFM

Return air intakes (918.10)

1. May a 16” x 20” return air grille with 75% free area be used on an 800 CFM system?

Answer: No, the velocity is too high, see below

A 16” x 20” grille has 320 sq. inches: only 240 sq, in is free area (320 x .75 = 240)

240 sq. in. / 144 sq. in. = 1.67 sq. ft.

Velocity = <u>CFM</u>
AREA (area in sq. ft.)

<u>800 cfm</u>
1.67 Sq. Ft. = 479 feet per minute (FPM)

Code says face velocity cannot be greater than 450 FPM

2.How many 10”, 16’ on center joists must be panned to handle 1200 CFM of return air.

Answer: 3

Each joist can handle up to 525 CFM 1200/525 = 2.28 joists

INTERNATIONAL FUEL GAS CODE

Confined and unconfined spaces (Definitions)
In the Definition chapter, look up confined and unconfined space.

According to the definition, is a room measuring 10’ x 10’ x 8’high with two 60,000 BTUH furnaces confined or unconfined?

Answer: confined, less than 50 cu. ft. per 1000 BTUH

1. divide the total btuh by 50, this give the cubic ft. limit.

<u>120,000</u> = 2400
50

If the room is less than 2400 cu. ft then it is a confined space. More than 2400 cu. ft, an unconfined space

The room is 10 x 10 x 8= 800 cu. ft., therefore it is confined

Combustion Air (section 304)

Using the two opening method, how many sq. inches must each duct be if outside air is horizontally introduced into a confined space containing a 140,000 Btuh furnace?

Answer: 70 sq, inches

140,000/2000=70

Divide to total BTUH in room by 2000

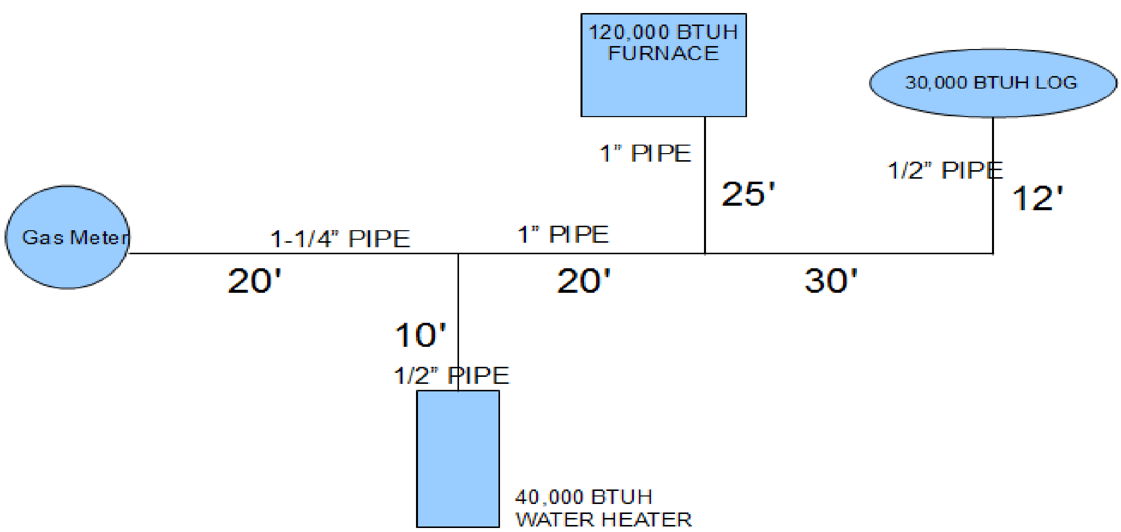
Gas Pipe Sizing

Appendix A gives an example for gas pipe sizing. Simply measure the distance between the meter and the farthest appliance, let's call this the **distance factor** then use this distance factor to size each **run** off the main line. Each time part of the load is dropped off the **main line** resize the line using the remaining load and same distance factor.

The toughest part is making sure you use the correct sizing table. Pay attention to specifics. Is the gas pressure less than 2 psi, .5 psi, 2psi, or 5 psi.? Is the pipe copper, or stainless steel?

For the example below we will use Table 402.4(2) 2007-9 IFGC

Note: 2003 and 2006 Gas Code may have slightly different charts but the methology is the same



The distance from the meter to the farthest appliance is 82' (distance factor). Looking at Table 402.4(2) go down to the 90 foot row. **You will size all pipe using this row.** The number 13 directly to the right of 90 means a ¼" *schedule 40 metallic pipe* will handle 13,000 btu's (approx. 1000 btu's / cu. ft. nat. gas). To get pipe size slide your finger across the 90 foot row until you find a pipe size large enough to handle the load.

To size the main

Beginning at the meter the first 20’ must handle the entire system load, 210,000 btuh

Thus the pipe must be 1-1/4” (good for 430,000btuh)

After dropping off the water heater load the next 20’ must handle 150,000 btuh.

Thus the pipe must be 1” (good for 205,000 btuh)

After dropping of the furnace the remaining 42’ must only handle the gas log, 30,000 btuh.

Thus, the pipe must be 1/2” (good for 53,000 btuh)

To size the runs off the main

The 10’ pipe between the main and water heater must handle 40,000 btuh.

Thus, the pipe must be ½” (good for 53,000 bthu). Remember to stay on the 90 foot row

The 25’ pipe between the main and the furnace must handle 120,000 btuh.

Thus, the pipe must be 1” (good for 205,000 btuh)

Size L-P gas piping the same way once you’ve passed the second stage regulator. To size between the first stage regulator (at the tank) and the second stage regulator (at the house), use the distance between regulators as the distance factor and size according to total connected load. **Be sure to read and use the correct sizing Tables.**

Venting (section 503)

Look at **paragraph** 503.5.4 and **figure** 503.5.4. This requirement is for <u>chimneys and single wall vents.</u>

Look at figure 503.6.6. This requirement is for <u>UL listed B and BW vents</u>

Single appliance -Table 504.2(1) Sizing vents

What size vent is needed for a 160,000 BTU} I naturally ventilated appliance if the total vent height is 18’ and the lateral 2’?

Under the height column you have to choose either 15’ or 20’. **Remember this,** the taller the vent the more capacity it has, therefore, if the 20’ row is used the vent may be under sized. **Always use the shorter height.** In this case use 15’. Now use the 2’ lateral and select a vent size under NAT. A 5” vent will handle only 129,000 BTUH, while a 6” vent will handle 225,000 BTU} I, therefore select a 6” vent.

Venting two or more appliances with a single vent –Table 504.3(1)

When connecting two or more appliances to a common vent, the smaller appliance should be connected above the larger appliance

This Table has two parts, the top section is for sizing **connectors,** and the lower section is for sizing the **vent.**

> **First,** size the connector of each appliance using vent height and connector rise.
> **Second,** size the vent using the total vent height and the total BTUH of all appliances connected to it. The same rule as above applies to height; always select the shorted height on the chart.

Example:

A standard 40,000 btuh water heater with a connector rise of 3 feet and a 120,000 btuh fan assisted furnace with a 1 foot connector rise are connected to a 22 foot common vent. Size the vent system.

Solution

Using the upper section of the chart size the **vent connectors** of each appliance.

Water heater

Since the vent height is 22 ft. use 20 on chart. Locate 3 feet under the connector rise column and slide to the right until you find at least 40 under a NAT column. At the top, it indicates a 3" **connector** will handle 42,000 btuh.

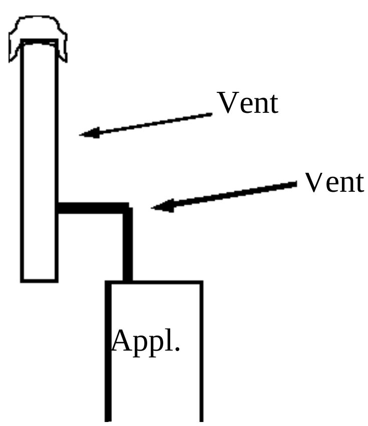
Furnace

Again, at the 20 foot vent height row, choose 1 foot in the connector rise column. Slide to the right until you find at least 120 under the FAN/MAX column. At the top it indicates a 5" **connector** will handle 157,000 btuh.

To size the common vent.

> Go to the lower section of the chart. Since one appliance is naturally vented and the other is fan assisted we will locate the 20 foot row and slide to the right until we reach 160,000 btuh (total of both appliances) under FAN+NAT. A 5" common vent will work, as it will handle up to 183,000 btuh.

Be sure to read and apply to vent sizing Paragraphs 504.2.2 and 504.2.3.



EXAM
PRACTICE QUESTIONS

1. A LICENSEE MAY HAVE HIS LICENCE REVOKED FOR WHICH OF THE FOLLOWING
   A. MISCONDUCT
   B. GROSS NEGLIGENCE
   C. INCOMPETENCY
   D. ANYOFTHEABOVE

2. IF A CONTRACTOR WORKS ON 15% NET PROFIT, WHAT WILL HIS SALES HAVE TO BE TO MAKE $75,000?
   A. $500,000
   B. $112,500
   C. $862.500
   D. $600,000
3. A CONTRATORS PAYS $750.00 FOR A FURNACE PLUS 7% SALES TAX. WHAT WILL HIS SALES PRICE BE IF HE WISHES TO MAKE 30% GROSS PROFIT
   A. $1028
   B. $1043
   C. $975
   D. $1146
4. THE MINIMUM THICKNESS OF REFRIGERATNT LINE INSULATION FORA RESIDENCE IS
   A. 1/4"
   B. 3/8"
   C. 1/2"
   D. 5/8'
5. THE DISTANCE FROM A METER TO A NATURAL GAS WATER HEATER (40,000 BTUH) IS30 FEET, 20 FEET FURTHER DOWN THE LINE ISA FURNACE (120,000BTUH). WHAT IS THE MINIMUM PIPE SIZE THAT MUST BE USED BETWEEN THE WATER HEATER AND FURNACE? (PRESSURE DROP =.05)
   A. 3/8"
   B. 1/2"
   C. 3/4"
   D. 1"

6. A HOUSE HAS A HEAT LOSS OF 48,000 BTUH AT 20 DEGREE OUTDOOR TEMPERATURE. WHAT IS THE HEAT LOSS AT 40 DEGREE OUTDOOR TEMPERATURE?
   A. 24.000 BTUH
   B. 28,800 BTUH
   C. 19,200 BTUH
   D. 18,000 BTUH
7. A CEILING HAS A TOTAL U VALUE OF .O7. WHAT IS THE NEW R VALUE IF R 19IS ADDED?
   A. 30
   B. 31
   C. 32
   D. 33
8. A 30' X 8' PARTITION (2 X 4 STUDS, GYPSUM ON BOTH SIDES. NO INSULATION) SEPARATES TWO ROOMS HAVING A TEMPERATURE DIFFERENCE OF 20 DEGREES. WHAT IS THE WINTER HEAT LOSS THROUGH THE PARTITION?
   A. 15,360 BTUH
   B. 3,535 BTUH
   C. 1,500 BTUH
   D. 2,609 BTUH
9. A 75,000 BTUH (INPUT RATING) 80% EFFICIENT FURNACE HAS A TEMPERATUR RISE OF 45 DEGREES. WHAT IS THE CFM?
   A. 1212
   B. 1667
   C. 1515
   D. 1175
10. A CUSTOMER MOVES UP FROM A 8 SEER TO A 14 SEER AIR CONDITIONER WHAT WOULD HIS YEARLY SAVINGS BE IF HE WAS PAYING $650 PER YEAR FOR AIR CONDITIONING?
   A. $325
   B. $260
   C. $197
   D. $279
11. A HEAT PUMP IN A RESIDENCE MUST BE CONTROLLED BY WHICH OF THE FOLLOWING
   A. PROGRAMABLE THERMOSTAT
   B. A DEVICE TO PREVENT ELECTRIC SUPPLEMENTARY HEAT FROM COMING ON IF HEAT PUMP CAN HANDLE THE LOAD ALONE
   C. A DEVICE THAT ALLOWS SUPPLEMENTARY HEAT OPERATION DURING DEFROST CYCLES EXCEEEDING 15 MINUTES
   D. AFOSSILFUELKIT
12. IN A ROOM THAT IS LARGE IN COMPARISION WITH THE SIZE OF EQUIPMENT, AN APPLIANCE THAT REQUIRES 18" CLEARANCE ON ITS SIDES MAY HAVE IT'S CLEARANCE REDUCED TO ___ "IF .024 SHEETMETAL WITH A VENTILATED AIR SPACE IS USED TO PROTECT

THE COMBUSTIBLE SURFACE.

A. 9”
B. 6”
C. 12”
D. MAY NOT HAVE CLEARANCE REDUCED

13. WHAT IS THE VELOCITY OF AIR 1400 CFM AIR IN A DUCT MEASURING 12” X 30”

A. 360FPM
B. 467FPM
C. 3.8FPM
D. 560FPM

14. CATEGORY I EQUIPMENT MAY BE VENTED WITH WHICH OF THE FOLLOWING TYPE VENTS

A. SINGLE WALL METAL
B. TYPE B
C. CHIMNEY WITH CLAY LINER
D. ALL THE ABOVE

15. TWO NATURALLY VENTILATING APPLIANCES WITH A COMBINED CAPACITY OF 128,000 BTUH ARE CONNECTED TO A COMMON B-VENT 18’ HIGH WITH TWO 90 DEGREE ELBOWS. WHAT SIZE COMMON VENT SHOULD BE USED?

A. 4”
B. 5”
C. 6”
D. 7”

16. THE MAXIMUM ALLOWABLE HOIZONTAL LENGTH OF A CATEGORY I APPLIANCE VENT CONNECTOR IS_______FEET FOR EACH INCH OF IT’S DIAMETER.

A. 1/2
B. 1
C. 1.5
D. 2

17. THE MAXIMUM HORIZONTAL LENGTH OF A SINGLE WALL METAL CONNECTOR IS %
OF THE HIEGHT OF THE CHIMNEY OR VENT.

A 50
B 75
C 100
D 150

18. IN ORDER TO SUPPLY OUTDOOR COMBUSTION AIR USING THE TWO OPENING METHOD WITH HORIZONTAL DUCTS, WHAT SIZE WOULD EACH DUCT BE TO HANDLE A 140,000 BTUH FURNACE?

A 7”X1 0”
B .3.5”X1 0”
C 14”X10”
D .8.5”X10”

19. IF A GALLON OF OIL CONTAINING 140,000 BTUS SELLS FOR $1.25, HOW MUCH WILL 1,000,000 BTUS COST WHEN USED IN AN 80% AFUE OIL

D .15

FURNACE?

A .$8.93

B .$14.00

C .$12.78

D .$11.16

20. IN WHICH OF THE FOLLOWING AREAS MAY A SINGLE WALL MOUNTED 4,000 BTUH UNVENTED GAS HEATER EQUIPED WITH AN OXYGEN DEPLETION SENSOR BE ALLOWED?
    A. SLEEPING ROOMS
    B. BATHROOM
    C. STORAGE CLOSET
    D. SURGICAL ROOM
21. GAS APPLIANCE CONNECTORS SHALL NOT PASS THROUGH ANY OF THE FOLLOWING <u>EXCEPT:</u>
    A. WALLS
    B. APPLIANCE HOUSINGS
    C. FACTORY BUILT FIREPLACE INSERTS
    D. FLOORS
22. RECLAIMED REFRIGERANTS SHALL NOT BE REUSED IN A DIFFERENT OWNER'S EQUIPMENT UNLESS TESTED AND FOUND TO MEET THE PUITY REQUIREMENTS OF;
    A. ASHRAE34
    B. NFPA54
    C. ASTMA53
    D. ARI700
23. AN AIR CONDITIONER HAS HIGH SUCTION AND LOW HEAD PRESSURES. WHAT WOULD BE A LIKELY CAUSE?
    A. DIRTY FILTERS
    B. BAD OR WEAK COMPRESSOR VALVES
    C. CLOGED METERING DEVICE
    D. DIRTY CONDENSER COIL
24. A HOUSE HAS A HEATING LOAD OF 46,800 BTUH. HOW MANY CFM ARE REQUIRED IN A ROOM WITH A LOAD OF 5200 BTUH, USING A FURNACE WITH A 1200 CFM BLOWER.

A 1112

B 112

C 133

D 468

25. WHAT IS THE DESIGN FRICTION RATE WHEN THE AVAILABLE STATIC

PRESSURE FOR THE DUCT SYSTEM IS .36 AND THE RUN WITH THE LONGEST EFFECTIVE LENGTH IS 375 FT.

A .10

B .08

C .05

D .15

26. A BLOWER WITH AN EXTERNAL STATIC PRESSURE OF .55" WC IS CONNECTED TO A 70 FT. LONG DUCT. THE SYSTEM INCLUDES REGISTERS AND GRILLS (.03 "WC EACH), A COOLING COIL (.15" WC),

D .15

AND FILTER (.10" WC). WHAT IS THE TOTAL AVAILABLE STATIC PRESSURE FOR SIZING THE DUCT?

A .24
B .17
C .33
D .08

27. A 12" ROUND DUCT HAS A RECTANGULALOR EQUIVALENT OF
    A. 14X8
    B. 15X8
    C. 16X8
    D. 17X8
28. THE VELOCITY OF 250 CFM OF AIR IN A FLEXIBLE, SPIRAL WIRE HELIX CORE DUCT SIZED AT .08" WC STATIC PRESSURE IS.
    A. 400 FPM
    B. 500FPM
    C. 750FPM
    D. 90O FPM
29. THE ONLY THING THAT CHANGES WHEN CONVERTING FROM A ROUND DUCT TO AN EQUIVALENT RECTANGLE DUCT IS.
    A. VELOCITY
    B. STATIC PRESSURE
    C. AREA
    D. CFM
30. FORA BUILDING TO BE MAINTAINED AT 70F HOW MANY BTUH ARE REQUIRED TO OFFSET 300 CFM OF 20F OUTDOOR VENTILATION?
    A. 6,000
    B. 1,400
    C. 6,600
    D. 16,500

31. THE AMERICANS WITH DISABILITIES ACT APPLIES TO ALL EMPLOYERS WHO HAVE OR M MORE EMPLOYEES?

A 10
B 15
C 25
D 50

THESE QUESTIONS WHERE PREPARED BY ***ENERGY MARKETING SERVICES*** IN ORDER TO GIVE EXAMPLES
OF THE TYPE QUESTIONS THAT ARE FOUND ON THE HVAC LICENSING EXAM. THEY ARE ONLY
REPRESENTATIONS OF QUESTIONS FOUND ON THE EXAM, NOT ACTUAL QUESTIONS

D .15

Answers to HVAC questions

1.D

2. A- $\frac{\$75,000}{.15}$ = \$500,000

3. D- \$750.00 cost
<u>52.50</u> tax(.07x\$750)
\$802.50 total cost
1.00-.30= .70 802.50/.70=**\$1146.42**

4. C- Residential building code Section N1 103.5, Table N1 102.5
5. C- Fuel Gas Code. Table 402.3 (2). The farthest appliance from the meter is 50 Ft. (30 Ft. +20 Ft.= 50 Ft.). Use column labeled 50. The section between water heater and furnace has to carry 120,000 BTUH (The water heater load has been dropped off). Go down the column until you find 120 (120,000) or greater. You should see 138 (138,000). To the right is 3/4"
6. B- At 20 degrees outdoor temperature the degree temperature difference (DTD) is 50 (70 indoor- 20 outdoor =50 DTD). Divide 48,000 BTUH by 50 DTD to get the heat loss per DTD (48,000/50 = 960 BTUH per DTD).
At 40 degree outdoor temperature the DTD is 30(70 indoor –40 outdoor =30 DTD). Since the heat loss per DTD is 960 BTU, multiply 960 BTU x 30. 28,800 BTU is the answer.

960 BTU per DTD x 30 DTD = 28,000 BTU

7. D- All U values must be converted to R values before adding or subtracting. In this case the U value (.07) must be converted to an R value.

R= 1
= 1/.07
= 14.2

14.28 (the old R value) + 19 (the added R value) = 33.28 (the new R value)

8. A partition is an *inside* wall separating rooms, therefore the surface air films on each side of the wall are still. Go to Table 10, Manual J- No. 1c indicates the R value for a non-reflective surface is .68 (there are two surfaces, one on each side of partion). Between the gypsum is a 3.5" air space (no insulation), No. 2 (d) with an R value of .94. The 1/2"gypsum, No. 4(d) has an R value of .45 (there are 2 pieces of gypsum< one on ead side of the wall) . Therefore the total R value is **3.20**

Heat Loss or BTUH = U x Area x TD

U = 1/R	**Area** = length x height	**TD =20**
= 1/3.20	= 30'x8'	
= .3125	=**240 sq. ft.**	

.3125 x 240 x 20 = 1500 BTUH

9. A- The furnace is 80% efficient, therefore its *output* is 75,000 x .80 = 60,000 BTU = CFM X 1.1 X TD TD (Temp Diff.) is also TR (Temp Rise)

CFM= BTU /1.1 xTD

TD= BTU / 1.1 x CFM

Since we are asking for CFM, use the CFM formula.

CFM = 60,000 / (1.1 X 45)

= 60,00/49.5

= 1212 CFM

10. D- old seer 8/ new seer 14 = .57
    .57 X $650 = $370.50
    $650- $371 (rounded) = **$279**
11. B- Residential building code, Section N1 103.2
12. B- Mechanical Code Table 308.6
13. D- Velocity = CFM / AREA (Area must be in Sq. Ft.)
    The area is 360 sq. inches (12" x 30" = 360 sq. inches)
    You must convert sq. inches to sq. feet, therefore:
    360 sq. inches/144 sq. inched per sq. ft. = 2.5 sq. ft.

    1400 CFM/ 2.5 sq.ft. = **560 FPM**

14. D- See Table 503.4, Fuel Gas Code
15. C- In appendix B, look at figure B-12. It shows two appliances connected to a common vent with one offset (two 90 degree bends). Now turn to section **504.3.5, Common vertical vent offset.** This paragraph says to reduce the capacities listed in the tables by 20 %. The lower section of Table 504.3 (1), **common vent capacity,** is the table we'll use to size the common vent. First, we have to determine which height to use, 15 ft. or 20 ft. As stated earlier, if the height of a vent falls between two choices, use the lower choice (15 ft.). To the right of 15 ft., look under each NAT + NAT column until you see 128 (128,000) or greater. The chart indicates a 5" vent will handle 144,000 btus, however, because of the offset, we must reduce this figure to 115, therefore a 6" vent must be chosen.

    Note: Be sure to consult all paragraphs under **Section 504, SIZING OF CATEGORY 1 APPLIANCE VENTING SYSTEMS** before making a final determination of vent sizes.
16. C- Fuel Gas Code, 503.10.9
17. B-Fuel Gas Code, 504.3.2

18. A- Fuel Gas Code, 304.11.1

Calls for 1 sq. inch per 2000 BTUH for *each* duct

140,000btuh/2000 btu =70 sq. inches

2000

A 10” x 7” duct = 70 sq. inches

19.D

$$\frac{1,000,000}{140,000} = 7.14 \text{ gals.}$$

The oil furnace is 80% efficient, therefore:

$$\frac{7.14 \text{ gals.}}{.80} = 8.925 \text{ Gals.}$$

If oil sells for $1.25, therefore:

$1.25 x 8.925 gals. = $11.16

20. B- Fuel Gas Code, 303.3, exception 3.
21. C-Fuel Gas Code, 411.1.2
22. D- Mechanical Code, 1102.2.2.3
23. B
24. C Room CFM = heating factor (HF) x room heat loss

HF = FURNACE CFM / HOUSE HEAT LOSS

=1200 / 46,8000

= .0256

Room CFM= .0256 x 5200 btuh

= 133 CFM

25. A Design static pressure = available static pressure x 100 / Total effective length

$$= \frac{.36 \times 100}{375}$$

$$= \frac{36}{375}$$

= .096 (.10,roundedup)

26. A-

Available static pressure = external static pressure – total resistance of all added components

External static pressure = .55 (from manufacturer's blower specs)

DEDUCT	
- registers	.03
- grilles	.03
-cooling coil	.15
- air filter	.10

Available static pressure (pressure left to design duct system = .24' wc

27. C-

Manual D, Chart 9 (You must use chart. Do not attempt to convert from square to round mathematically).

Locate 8” (one side of duct) across the top; slide your finger down until you find 16” (round duct size). Use 16.2”, the closest duct size in the chart, 15.8

is too small. Slide finger to left hand column and you will see 16” (the other side of duct).

28. B-

Be sure to use correct friction chart in Manual D. In this case it will be Chart 7 (**Flexible, Spiral Wire Helix Core Ducts).** Locate .08 (static pressure) at bottom of chart. Slide finger up to 250 CFM. Diagonal line indicates **500 FPM.**

29. C- This is a tricky question. If a conversion chart is used then the area of the square or rectangular duct will be larger than the round duct, thus compensating for the increased friction loss of square duct. If the areas are the same for both round and square duct then the friction loss will be higher for the square duct, therefore the velocity, static pressure and cfm will be different.

30. D-

BTUH=CFMx 1.1 xTD

= 300x1.1x(70-20)= 300x1.1x50

= 16,500 BTUH

31. B- Business Project Management for Contractors, page 7-4