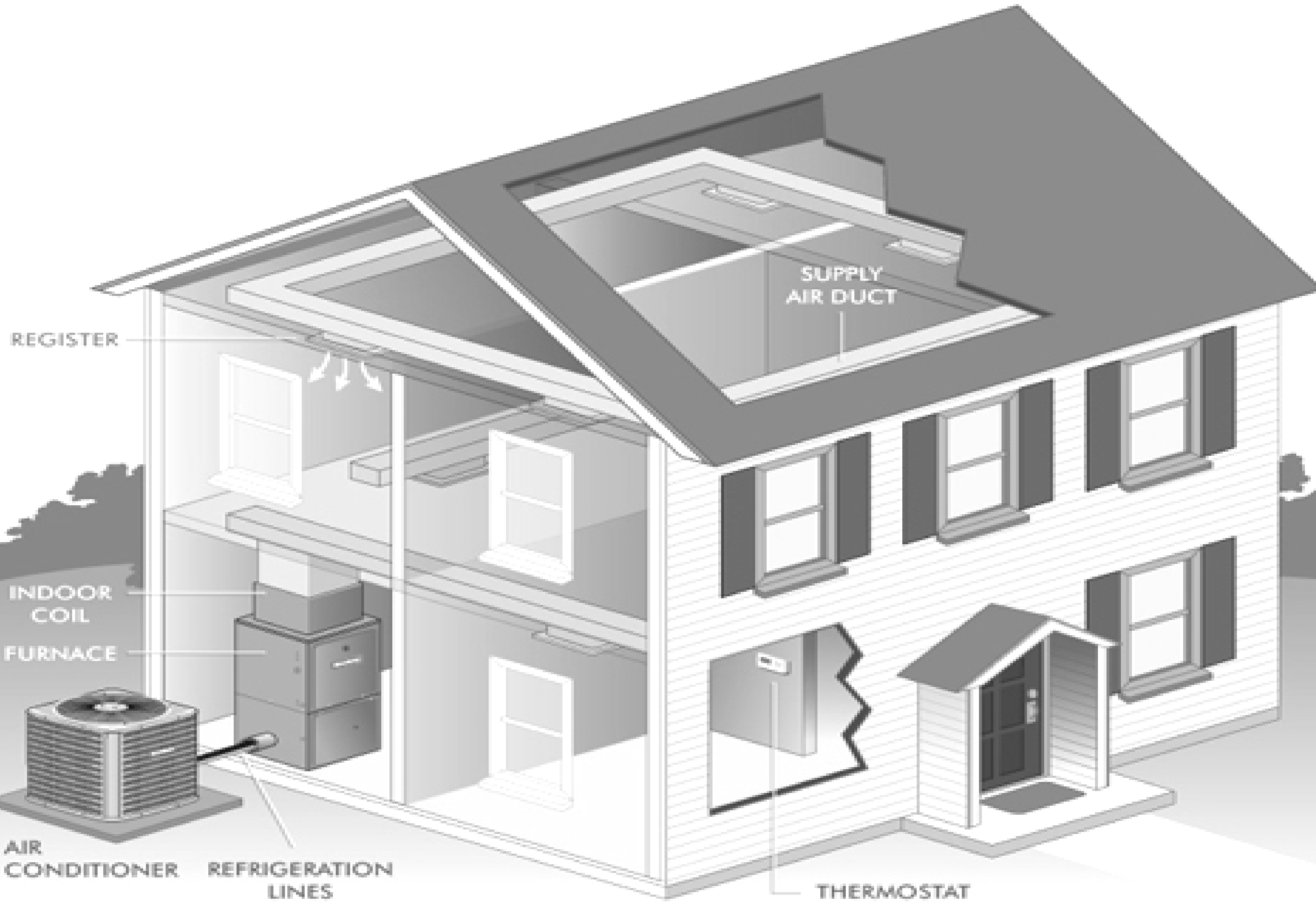

A GUIDE TO PASSING THE HVAC EXAM

Covers Manuals J.D. and N. Int. Mechanical Code
International Fuel Gas Code
International Energy Code
Business Calculations

ENERGY MARKETING SERVICE

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How to access the EMS practice HVAC licensing exam

(approximately 150 questions)

Go to www.johnrwhite.net and click on the puppy at the upper left corner.

The answers are at the end of the exam

Note: Due to amendments by each state some answers to this test may not agree with your code book. In which case, accept your state's code answer.

For a free demo of our *EMS HVAC load calculator* click on or enter the following web address into the address bar of your computer
http://johnrwhite.net/try_a_free_demo_version_now.htm

ABOUT THIS GUIDE

This guide 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 materials required for study. Furthermore, it is not an approved reference to carry into the exam room.

Preparing a study guide for the HVAC exam is a challenging event, as many states and jurisdictions that have adopted the International Codes have added their own amendments. For example, the IMC states the dryer vent shall be no longer than 35 feet. Some states, however, have amended this to 45 feet. Some tables in this guide have had footnotes added to tables. In some instances, entire sections have been added or deleted. Therefore, our section numbers may not correspond to those in your state's IPC; however, they should be close. If any information in this guide disagrees with your state's IPC, then accept your code as the final authority.

The following references were used to produce this study guide. The author understands some states do not test for knowledge of load calculations (Manuals J and N). If this is the case with your state you may skip those chapters. However, it certainly will not hurt to learn how to perform a load calculation. After all, would you purchase an air conditioner from a contractor who is unable to properly size a system?

- 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

Send questions and comments to jrwmtw@gotricounty.com

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Chapter 1

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

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

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

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

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

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

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

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

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

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

What is a load calculation?

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

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

Why do a load calculation?

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

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

Sizing rules for *heating* (ACCA):

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

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

Sizing rules for *air conditioners* (ACCA):

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

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A few basics before getting started

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

1st law of thermodynamics

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

2nd law of thermodynamics

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

How structures lose or gain heat

Heat is transferred by conduction, radiation or convection

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

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

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

BTU

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

BTUH

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

SPECIFIC HEAT

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

SENSIBLE HEAT

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

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

figure 1

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

Design temperature and design temperature difference (TD)

Table 1A

Outdoor Design Conditions for the United States

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

figure 2

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

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

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

The inside design temperature should always be:

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

*unless otherwise specified

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

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

Answer: 70F - 23F = 47 DTD

Latent heat

The heat required to change the state of a substance. It cannot be measured with a thermometer. For example, if we heat one pound of water ten degrees, it would take 10 BTUs, according to our definition of sensible heat. However, when we change the state of the water from liquid to vapor (steam), we are not changing the temperature, only the state. It also takes energy or BTUs to change the state. This is called *latent heat* or *latent heat of vaporization*, to be specific. **It takes 970 BTUs to change the state of one pound of water from liquid to vapor or vapor to liquid**, therefore the latent heat of vaporization of water is 970**.** When an air conditioner removes moisture from the air, it is converting (changing the state) water vapor to liquid, which flows down the drain line and out of the house. If you were to catch this water in a bucket and determined that 1.5 gals per hour were being produced by the air conditioner, then it would take 12,120 BTUH of capacity to produce the latent heat necessary to remove the moisture. Below is the formula.

BTUH = latent heat x weight

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 BTUs (latent heat)

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

R-Value

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

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

U value

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

The U value is the number of BTUs that pass 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. A U-value can to said to be the *rate of conduction*

U=1/R

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

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

U= 1/R

U= 1/19

U=.0526

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

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

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

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

BTUH = U x TD X AREA

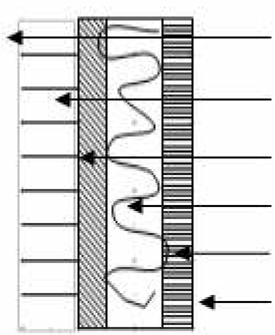
=.0526 x 50 X 16'

= 42.08

Once you know the U value, the square footage and the temperature difference, you can calculate the BTU heat loss or gain per hour through a substance. However, walls, floors and ceilings are not made up of just insulation. A wall may be made up of brick, sheathing, insulation and sheetrock, each of which has its own R value. The R value of each component must be added together to obtain the total R value. Then we simply take the reciprocal (1/R) and get the total U value of the wall. For a list of R-values, locate a table titled "**R Values of Common Building Materials"** in Manual J8, or go to:

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

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



	R-value	
outside air surface (winter)	.17	
4" brick	.44	(4' x .11)
R- 1.32 sheathing	1.32	
R- 11 insulation	11.00	
1/2"gypson	.45	
inside air surface	.68	
Total R-value	**14.06**	

figure 3

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

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

U = 1 /R

U = 1/14.06

U = .071

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

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

The formula BTUH = U x DTD x AREA

We know the U value = .071

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

To get the DTD we need to go to Table 1, look up Birmingham, AL and find the outdoor winter design temperature, which is 23 degrees (figure 2). You were also told that unless otherwise stated, to use 70 degrees as the indoor winter design temperature. Therefore, the design temperature difference (DTD) is 70F - 23F = 47F.

Now complete the following simple calculation:

BTUH = U x DTD x AREA

=.071 x 47 x 360

= 1201

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

What is an HTM?

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

HTM = U x DTD

=.071 x 47

=3.337

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

BTUH = HTM x AREA

BTUH = 3.337 x 360

BTUH = 1201

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

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

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

Since Manual J8 does not give you the HTM. You must create your own HTM using the above formula. Go to Table 4A, construction number 16C-30. you will find a ceiling with R-30 insulation has a U value of .032. To get the HTM for a 47 degree TD simply perform the following:

HTM = U x DTD

= .032 x 47

= 1.504

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

BTUH = HTM x AREA

= 1.504 x 1678

= **2524**

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

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

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

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

BTU = CFM x 1.1 x TD

CFM – cubic feet per minute

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

TD - temperature difference or design temperature difference

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

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

BTU = CFM x 1.1 X TD

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

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

How to change air changes per hour to CFM.

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

OR

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

Where:

Volume = length x width x height,

Or

Volume = area x height

.0167 is the decimal equivalent of 1/60

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

CFM = (15,102 x .38)/60 MINUTES

CFM = 5739/60

CFM = 96 (rounded from 95.65)

Add the fireplace

96 + 13 = **109 CFM**

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

BTU = CFM x 1.1 x TD

BTU = 109 x 1.1 x 47

BTU = 5635

Calculating infiltration for air conditioning (heat gain).

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

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

BTUH (Sensible) = CFM X 1.1 X TD

While the formula for latent heat gain is

BTUH (Latent) = CFM x .68 x Grains Difference

.68 is a constant

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

CFM = (Volume x ACH)/60

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

CFM = (15,102 x .2)/60

= 3020/60

= 50.33

Now apply the two formulas

Sensible heat gain (BTUH) = CFM x 1.1 x TD

= 50.33 x 1.1 x 17

= 941 BTUH

Latent heat gain (BTUH) = CFM x .68 x grains diff.

= 50.33 x .68 x 41

= 1402 BTUH

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

Duct loss and duct gain

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

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

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

To determine the duct loss factor, multiply:

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

.180 x 1.85 x 1.53 = .509

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

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

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

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

= (.607 x (267/312)) + (.393 x (95/138))

= (.607 x .856) + (.393 x .688)

= .519 + .270

= **.789**

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

Final or adjusted duct loss = .509 x .789

= **.401**

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

Duct loss factor = .401

.401 x 43,678 = BTUH duct loss

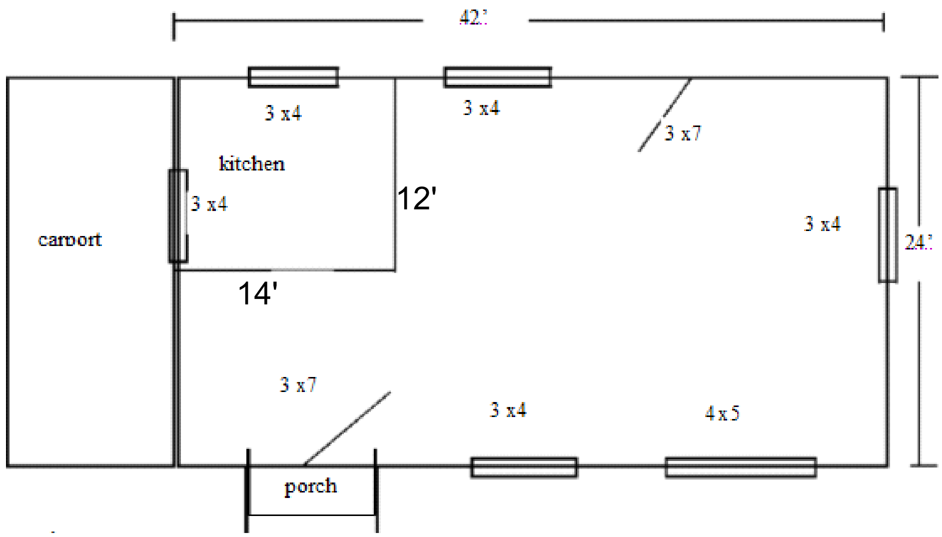
= 17,515 BTUH duct loss

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

Total heat loss with duct loss 61,193 BTUH

Let's do a *heat loss* calculation

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



Sample House

LOCATION- RALIEGH		
Duct Loss use Table 7H Manual J8 TRUNK AND BRANCH DUCT SYSTEM, LOCATED IN CLOSED CRAWLSPACE, R-2 INS, UNSEALED, Surface area of supply 260 sq.ft- return 98 sq.ft.		
INFILTRATION- Use Table 5A Manual J8 TIGHTNESS OF CONSTRUCTION- AVERAGE		
8 FT. CIELINGS		
COMPONENT	**J7 HTM**	**J8 HTM**
WINDOWS – DOUBLE CLEAR GLASS WOOD FRAME	27.6 (TABLE 2 NO. 1A)	.57 X 50 DTD = 28.5 (TABLE 2A NO. 1 D)
DOORS- METAL POLYSTYRENE CORE WITH STORM	15.9 (TABLE 2 NO. 11 D)	.21 X 50 DTD = 10.5 (TABLE 4A NO. 11O)
WALLS- WOOD FRAME, R-1 1 INS, WOOD SHEATHING	4.5 (TABLE 2 NO. 12C)	.097 X 50 DTD = 4.85 (TABLE 4A NO.12B 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 3

HEATING LOAD				
row		AREA/VOLUME	HTM	BTUH
1	solar gain			
2	gross walls	1056		
3	windows	80	28.5	2280
4	doors	42	10.5	441
5	net walls	934	4.85	4529
6	ceilings	1008	2.45	2469
7	floors	1008	5.55	5594
8	infiltration sensible (1)	8064	winter ACH .45	3326
9	people sensible	No. ______		
10	appliances			
11	sub total			18,639
12	duct loss 34% (2)		.34 x 18,639	6337
13	duct gain ____%			
14	total sensible load			24,976

Figure 4

1. Infiltration BTUH = CFM x 1.1 x DTD

CFM = (house volume x ACH)/60 minutes

= (8064 x .45) / 60 = 60.48

BTUH = 60.48 x 1.1 x 50 = **3326** BTUH

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

First determine the SAA (surface area adjustment)

SAA=(.682 x (220/260)) +(.318 x (98/84))

= (.682 x .846) + (.318 x 1.166)

= .577 + .371

= .948

.110 x 1.63 x 2.02 x .948 = **.343 (Rounded to 34%)**

Explanation of heating load calculation

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

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

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

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

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

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

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

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

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

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

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

ROOM BY ROOM CALCULATION

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

Performing a load calculation for an individual room is done in the same manner as a whole house calculation. You must, however, keep in mind to enter in the *area* column **only areas exposed to the outdoor temperature**. For example, although the kitchen (12' x 14") has 52 linear feet of wall area, only 26 linear feet is exposed to the outdoors. Therefore enter 208 in the *area* column (26' x 8'). If the house were two stories, where the room above is heated, you would enter 0 area for the kitchen ceiling, as the ceiling is not exposed to the outside, but exposed to the heated second floor.

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

WAR= exposed room wall area/whole house wall area

then

Room infiltration = WAR x whole house infiltration

example infiltration calculation for kitchen:

Exposed wall area of kitchen = 26' x 8'

= 208 sq.ft.

war = 208/1056

= .197

room inf. = .197 x 3326

= 655 BTUH

ROOM-BY-ROOM HEAT LOSS (Kitchen)

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

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

The Heat Gain Calculation

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

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

Turn to Table 4A, construction no. 12B-0s w/m. To the right, under U-value with wood studs, you will see .097 listed as the U value. When figuring a **heat loss** we could arrive at the correct HTM by simply multiplying the TD by the U factor (HTM = U 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. Table 1A (figure 2) gives the daily range in the last column. Birmingham's daily range is medium (M)

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

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

To get the cooling HTM, use the following formula:

COOLING HTM = U x CLTD

=.097 x 24.1

= 2.34.

Solar gain through windows or glass

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

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

Determine shaded/unshaded glass area

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

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

> Our sample window is 5 ft. high and 3 ft. wide, facing south. The overhang sticks out 18" and the top of the window begins 6" below the overhang (you may want to draw this out). The home is located 36 degrees north latitude.
>
> Using Table 3E, fill in the blanks under column #1. A sample calculation may be found in Section 19 - 13. If you do all the math correctly, the results should show 14.37 sq. ft. shaded and .63 sq. ft. unshaded.

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

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

SOLAR GAIN THROUGH GLASS					
	Total glass	SHADED	UNSHADED	HTM	BTUH
NORTH	24	24			
NE/NW					
SOUTH	32	24	8	38	304
SE/SW					
EAST	12		12	73	876
WEST	12	12			
TOTAL NORTH AND SHADED		60		24	1440
TOTAL SOLAR GAIN					2620

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

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

All unshaded areas are multiplied by the corresponding HTM.

	LOAD CALCULATION					
			HEATING		COOLING	
		AREA/VOLUME	HTM	HEAT LOSS	HTM	HEAT GAIN
1	solar gain					2620
2	gross walls	1056				
3	windows	80	28.5	2280		
4	doors	42	10.5	441	6.51	273
5	net walls	934	4.85	4529	2.82	2634
6	ceilings	1008	2.45	2469	2.45	2467
7	floors	1008	5.55	5594	2.21	2227
8	infiltration sensible (1)	8064	winter ACH .45	3326	summer ACH .23	678
9	people sensible	No. 4			230	920
10	appliances					1200
11	sub total			18,639		13023
12	duct loss 34%			6337		
13	duct gain 22%					2865
14	total sensible load			24,076		15,888
15						
16	infiltration latent (2)	8064			summer ACH .23	861
17	duct gain latent (3)				see below	2462
18	people latent	No. 4			200	800
19	totall latent load					4123
20	TOTAL LOADS		HEATING	24,976	COOLING	20,011

Row 8 (cooling column)

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

= ((AC/HOURXVOL.)/60) x 1.1 x TD

= ((.23 x 8064)/60)) x 1.1 x 20

= 30.9 x 1.1 x 20

= 678

Row 13

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

First determine the SAA

SAA=(.682 x (220/260)) +(.318 x (98/84))

= (.682 x .846) + (.318 x 1.166)

= .577 + .371

= **.948**

duct gain = .070 x 1.63 x 2.02 x .948

= .218 (rounded to 22%)

Row 16

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

Latent heat as you will remember is the heat required to remove the moisture from the air. Infiltration of humid outdoor air and people are the main sources of moisture in a residence. People contribute about 200 BTUH of latent heat per person. The amount of latent heat brought in from outside air is dependent upon the CMF and its amount of moisture (measured in grains/lb. 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, Birmingham, AL, you will see under grains difference a choice between 55%, 50% and 45% relative humidity. We will use the column under 50% (meaning we want to achieve 50% RH in the house) and find 41 will be the grains difference (the amount of moisture we need to remove from the inside air). Manual J is leaving it up to you to decide which RH to strive for. 55% should be the upper limit as mold and mildew will begin to become a problem above 60% RH.

.68 is a constant.

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

Latent heat gain (infiltration) = CFM x .68 X Grains Diff.

= 30.9 x .68 x 41

= 861 BTUH

ROW 17

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

Duct gain (latent) = base case latent heat x leakage correction x LGA

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

Duct gain (latent)= 542 x 4.02 x (95/84)

= 542 x 4.02 x 1.13

= 2462 BTUH

ROW 18

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

People (latent) = No. people x 200

= 4 x 200 =800 BTUH

Peak Load Procedure

When to use the peak load procedure

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

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

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

IMPORTANT NOTES

Wall, is it above or below grade?

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

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

Concrete slabs on grade

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

32.9 x 60 = 1974 BTUH.

Basement floors

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

$$HTM = 55 \times .022$$

$$= 1.21$$

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

$$= 1694$$

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 this section.

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, its 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:

Annual fuel consumption = <u>House heat loss x degree days x 24</u>

Efficiency of furnace X btu content of fuel X DTD

Let's 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.

Fuel = 24,976 BTUs x 24 x 3440 degree days

.80 efficiency x 1025 BTUs/cu. ft. x 50 degrees DTD

= <u>2,062,018,560</u>

41,000

= 50,293 cu. ft. gas/year

Since gas is sold per hundred cubic feet (therm.), we must divide 50,293 by 100 in order to get therms.

Therm. = 50,293 BTU/100 cubic ft. gas

= 502.93

Annual operating costs = 502.93 therms. x $1.20

$603.51 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. This value is expressed as a percentage.

SEER (Seasonal energy efficiency ratio) – This is the average number of BTUs an air conditioner will produce for each watt of energy consumed. An air conditioner with a SEER of 12 will produce 12 BTUs per watt input.

HSPF (Heating seasonal performance factor) – This is the average number of BTUs a heat pump will produce for each watt of energy consumed. A heat pump with an HSPF of 7 will produce 7 BTUs per watt input. Although it's popular to sell heat pumps by their SEER rating, it is equally important to promote its 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:

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

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 is A and the 12 SEER system as **B**.

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

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

$$= \$416$$

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

Degree day

Suppose Monday night the temperature went 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

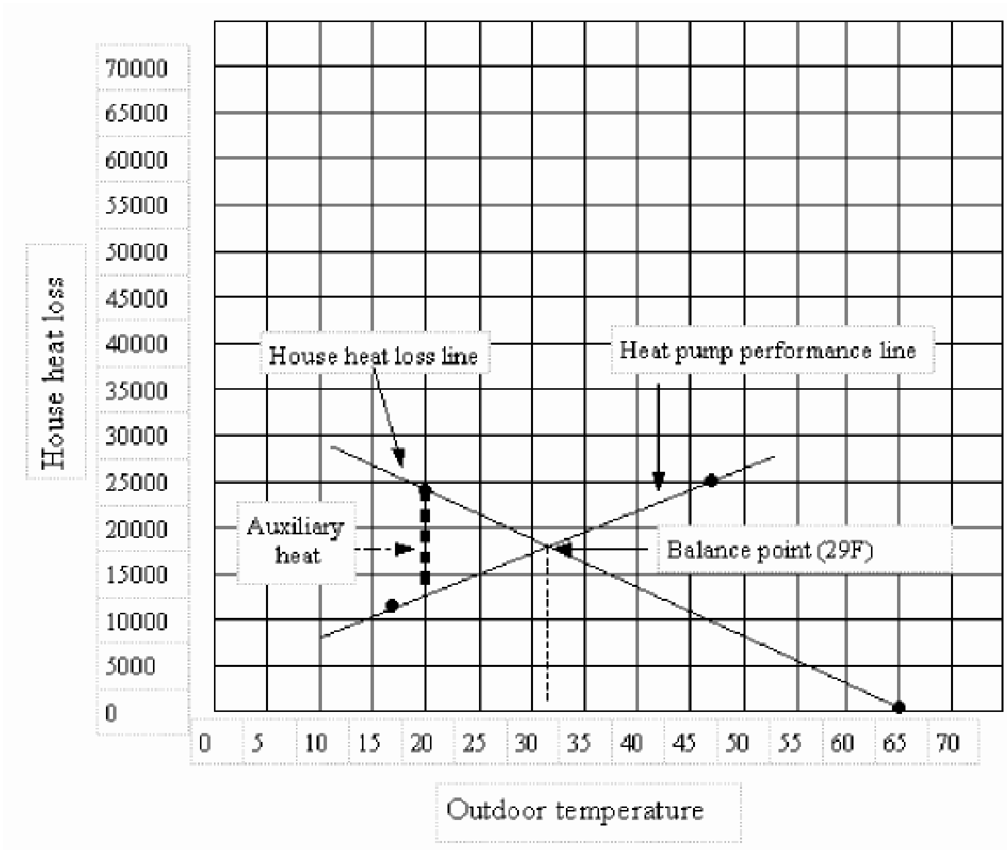
At 70-degree outdoor temperature our sample house will have 0 heat loss. At 20-degree outdoor temperature our house will have a 24,976 BTUH heat loss. Let's say we installed a 2-ton heat pump, 24,000 BTUH (*All right, the heat gain was only 10,979, so we're grossly over sizing the unit. If the house were not just 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 than 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 (24,976 @ 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) the heat loss at the outdoor design temperature and (2) the heat pump capacity at that temperature. The difference must be made up with auxiliary heat. We know the heat loss is 24,976 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 12,476 BTUH (24,976 - 12,500). If electric resistance heat were used as the auxiliary heat then we would divide the BTUH by 3413 to determine the KW (3413 BTUs = 1 KW).

12,476/3413 = 3.61 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 that it is time consuming. The main point 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 BTUs = 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

= 24,976/50

= 499.52 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 BTUs / degree temp. diff.

= 27.5 x 499.52

= **13,736 BTUH**

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

FUEL BTUs = HEAT LOSS x HOURS

= 13,736 BTUH x 589 HOURS

= 8,090,504 BTUs

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 BTUs for all bins.

To obtain the amount of fuel used:

FUEL = TOTAL OF BIN BTUs/(EFFICIENCY x BTU CONTENT OF FUEL)

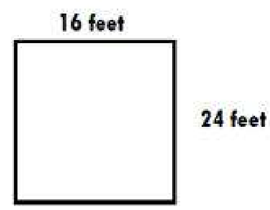
The above example is for fossil fuels and electric furnaces only. Using the bin method for a heat pump requires knowing the coefficient of performance (COP), capacity and characteristics of the auxiliary heat for each bin. The calculation becomes quite encumbering. Appendix A-4 offers an explanation of the procedure for those interested in pursuing this topic.

Chapter 2

Useful Formulas

How to Calculate Area

Square or rectangle
area = length X width

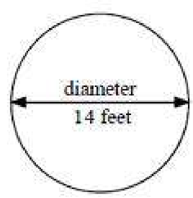


Area = L X W
= 16 ft. x 24 ft.
= 384 square feet

Circle
area = π X Radius^2 or πR^2

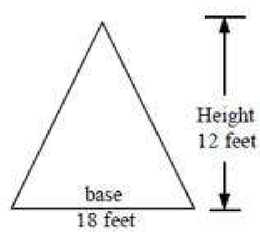
$\pi = 3.14$

Radius = 1/2 X Diameter



area = π X Radius^2
= 3.14 X 7 FT. X 7 Ft.
= 153.86 square feet

Triangle
Area = $\frac{\text{height X base}}{2}$
or
Area = 1/2 base X height



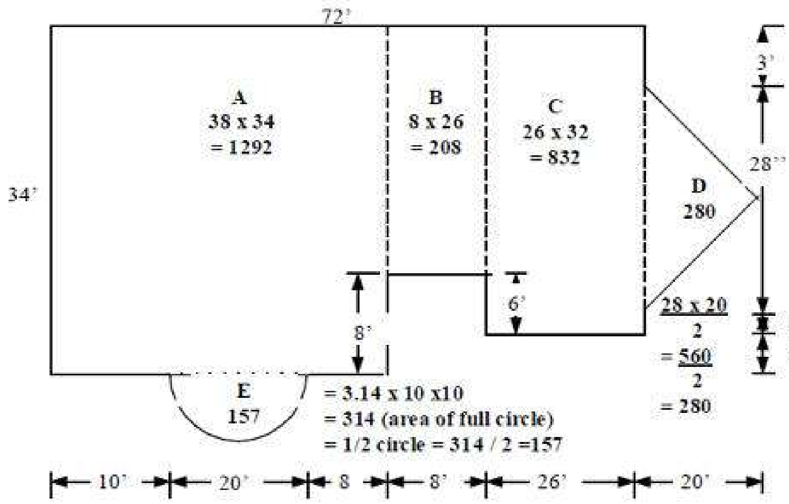
Area = $\frac{\text{height X base}}{2}$

= $\frac{\text{12 feet X 18 feet}}{2}$

= $\frac{\text{216 square feet}}{2}$

= 108 square ffet

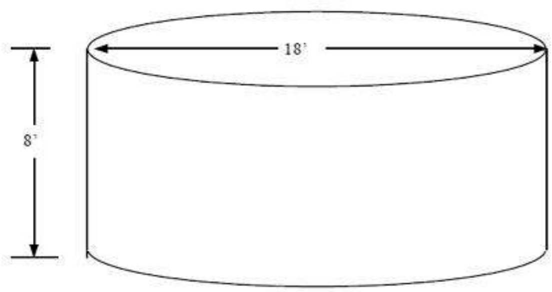
How to calculate the square feet of a home



1. Section house into rectangles (dotted lines).
2. Calculate area within each rectangle (L X W)
3. Use formulas above to calculate area of triangle and half circle.
4. Add all areas together.
5. A 1292
   B 208
   C 832
   D 280
   E 157

Total 2769 Square feet

How to calculate the area of circular walls



Earlier we learned how to calculate the area of a circle using the formula, area = π X Radius^2
We now need to learn a new formula that calculates the circumference of a circle. The circumference is the same as the perimeter of a rectangular wall. If we know the circumference then we can say the area of a circular wall = circumference X height.

Circumference = 2 X π X Radius or $2\pi R$

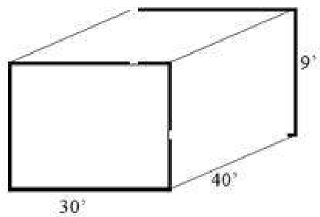
Therefore, the area of the above wall is calculated as follows:

STEP 1. Circumference = 2 X 3.14 X 9'
= 56.52

STEP 2. Wall area = 56.52 X 8'
= 452.16 Sq. ft.

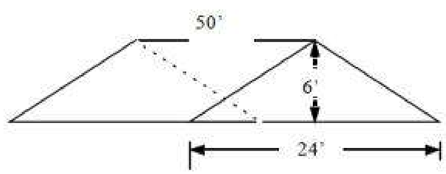
Calculating Volume

Volume of a rectangular building = length x width x height



Volume = length X width x height
= 30' X 40' X 9'
= 10,800 cubic feet

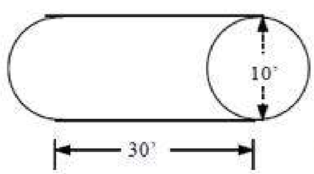
Volume of a triangular building = area of triangle X length or height



Step 1. Area of triangle = $\frac{\text{length X height}}{2}$
= $\frac{24' \text{ X } 6'}{2}$
= 72 sq. ft.

Step 2. Volume of triangle = area X length
= 72 sq. ft. X 50'
= 3600 cubic feet

Volume of a cylinder = Area of circle X length of cylinder



Step 1. Area of circle = π X Radius^2 or πR^2
= 3.14 X (5' X 5')
= 3.14 X 25 square feet
= 78.5 square feet

Step 2. Volume of cylinder = area of circle X length of cylinder
= 78.5 square feet X 30'
= 2355 cubic feet

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?

Convert the U value to R value: 1/.20 = R-5

Add: R-5+R-11=R-16

Convert new R value to new U value: 1/16 = .0625

HTM =

U x TEMPERATURE DIFFERENCE

HEAT LOSS =

BTUH = U x TD x AREA

or

BTUH = HTM x AREA

SENSIBLE HEAT GAIN OR LOSS DUE TO INFILTRATION OR VENTILATION=

CFM x 1.1 x TEMPERATURE DIFF.

The above formula may be changed around to determine temperature rise or CFM through a furnace.

TR = BTUH/(1.1 x CFM)

CFM = BTHU/(1.1 x TR)

LATENT HEAT GAIN DUE TO INFILTRATION OR VENTILATION =

CFM x .68 x GRAINS DIFF.

CFM DUE TO INFILTRATION =

CFM = VOLUME X AIR CHANGES PER HOUR/60

Chapter 3

A Guide to Manual N

The principles of Manual N are basically the same as those of Manual J. The methodology used to perform a *heat loss* calculation is virtually the same for a residence as a commercial building. However, the *commercial heat gain* calculation involves the inclusion of internal loads, number of people, infiltration from traffic, required ventilation and time of day. which has 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 internal load 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, to determine the true peak load, it may be necessary to perform two load calculations, one at 3:00 PM, the hottest time of day, and one at noon, when the restaurant is going full blast.

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). There are no HTM tables in Manual N, 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 CLTD x Area (for doors, walls and ceilings)

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

The **CLTD** (cooling load 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 construction number 13DA-0oc, Table 4A. 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 CLTD x AREA

Step 1. Determine the U value.

Go to the Table and select the U-value- .091

Step 2. Determine the CLTD

The last column to the right in Table 4A indicates that this wall is an group I. Go to Table 4B; under Group I, 3PM (15), South. You will see the CLTD is 17.

Step 3. Determine the Area

Area = Length x height = 10' x 200'

= 2000 sq. ft.

Step 4. Determine the heat gain

BTUH = U x CLTD x Area

= ..091 x 17 x 200

= 3094 BTUH

- Calculating the load for doors and ceilings is done just like walls. Use Table 4B for CLTD.
- For floors BTUH = U x PTDH x Area

  see construction numbers 19, table 4B

WINDOW LOADS

For **winter** load (heat loss) calculations use Table 2A to determine U value.

Example:

300 sq. ft. of double pane construction No.1c-gpo-h, metal no break, bare glass @ 50 degree temperature difference

Solution:

BTUH = U x TD x Area

1) Go to table 2A to find the U value for the described glass. The correct U value is .87.
2) BTUH = .87 x 50 x 300

   = 13,050

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

Question?

Assume the above window is facing south at 36 degrees latitude with no internal or external shading, what is the solar gain at 12:00 PM?

Solution:

First get the HTM: (see table 3D-1 for to obtain formula)

HTM = (PSF X CLF X (SHGC/.87)) + (U X CTD)

PSF - Table 3D-2 (we'll use midsummer for illustration) = 131

CLF - Table 3D-3 (we'll use medium construction)= .52

SHGC- Table 2A = .54

U - Table 2A = .87

CLT - cooling temp. diff. or actual temperature diff = 20F

HTM = (131 x .52 x (.54/.87)) = (.87 x 20)

= (131 x .54 x .62) + (.87 x 20)

= 43.9 + 17.4

= **61.3**

Then use the following formula

BTUH = HTM x AREA

61.3 x 300 sq. ft.

18,290

INFILTRATION AND VENTILATION

Loads presented by infiltration and ventilation are calculated the same as discussed in Guide to Manual J. Air changes per hour are found in Tables 5A thru 5D.

This formula below is used to determine the sensible heat gain (summer) or sensible heat loss (winter) due to infiltration

BTUH (Sensible) = CFM X 1.1 X TD

This the formula for latent heat gain (summer)

BTUH (Latent) = CFM x .68 x Grains Difference

.68 is a constant

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

Example: A 7500 square foot, low rise commercial building, semi-tight construction, 10 foot ceilings, 16 degree TD located in Charlottesville, VA.

What is the summertime infiltration load if 50% RH is desired in the building?

Solution:

1. Determine the CFM

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

   = (75,000 cubic ft. x .38)/60

   = 28,500/60

   = 475 cfm

2. Determine the sensible heat gain via infiltration

   BTUH (Sensible) = CFM X 1.1 X TD

   = 475 x 1.1 x 20

   = 10,450 btuh

3. Determine the latent heat gain via infiltration

   BTUH (Latent) = CFM x .68 x Grains Difference

   = 475 x .68 x 37

   = 11.951 btuh

4 Total heat gain due to infiltration

   Total heat gain = sensible + latent

   = 10,450 btuh + 11,951 btuh

   = 22,401 btuh

INTERNAL LOADS

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

A commercial building could have any number of appliances, motors, people and lighting fixtures. The heat produced by these items must be added to the building air conditioning load. Manual N offers Tables 6A-6M, which lists the loads of most items found in a commercial building.

To convert watts to BTUH:

BTUH = watts x 3.413

How to calculate loads due to intermittent operation;

Loads, such as machinery that do not operate continuously may be calculated as follows:

BTUH = watts X 3.413 x use factor*

*The use factor is minutes per hour used / 60

Example:

A machine rated at 2500 watts operates for 20 minutes out of the hour.

BTUH = 2500 x 3.413 x (20/60)

= 2500 x 3.413 x .33

= 2590 BTUH

Lighting load- Table 6A lists the wattage of various type lighting. Turn to Table 6A and find a 48 inch standard florescent lamp (T12). Notice the lamp is rated at 40 watts. If the fixture holds 2 lamps then the total *fixture wattage* is 92 as opposed to the two lamps, which total 80 watts. The reason the fixture is rated at 92 watts is because the *ballast* adds about 15% to the lamp wattage.

One rule of thumb for calculating lighting loads (BTUH) is to multiply incandescent wattage by 3.413 and multiply florescent wattage by 4.2

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 (RH). Low RH causes dry skin and membranes, and at 20% RH or below, causes static electricity and drying out of furniture and building materials.

When heating equipment is used to supply humidification via evaporation, the humidification load can be significant and may be calculated as follows:

BTUH = 1064 x pounds of water per hour

1064 is the latent heat of vaporization for water (BTUH)

The pounds of water per hour needed to maintain a target indoor relative humidity is calculated as follows using Table 12:

pounds of water per hour = .000645 x outdoor CFM x (indoor grains-outdoor grains)

Using the infiltration example above, calculate the btuh required to humidify the 7500 Sq ft. building:

1. Determine the pounds of water per hour needed

lbs H_2O/hr = .000645 x 475 x (12.0 - 38.0)

= .000645 x 475 x 26

= 7.96 lbs of water

2. Determine BTUH required to humidify.

BTUH = 1064 x pounds of water per hour

= 1064 x 7.96 lbs

= 8469 BTUH's

8469 btuh's must be added to the heating load for humidification, *only when the heating equipment will be used to evaporate the water.*

Chapter 4

Duct Sizing in Three Easy Steps

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 need to calculate only three things:

1) What is the *available static pressure* for the ductwork?
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 it's 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, 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.w.c., you will get 1400 CFM." Therefore, sizing a system using the specified static pressure is important in order to assure correct CFM.

Blower Performance			
	External Static — IWC		
CFM	High	Med	Low
1200			0.45
1250		0.49	0.30
1300		0.37	0.08
1350		0.25	
1400	0.62	0.14	
1450	0.55	0.04	
1500	0.47		
1550	0.39		
1600	0.31		
Tested with wet coil and filter in place. Subtract pressure drop associated with resistance heating coil.			

Figure 8-1

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.

Note: 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, 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 following formula:

ADJUSTED STATIC PRESSURE =

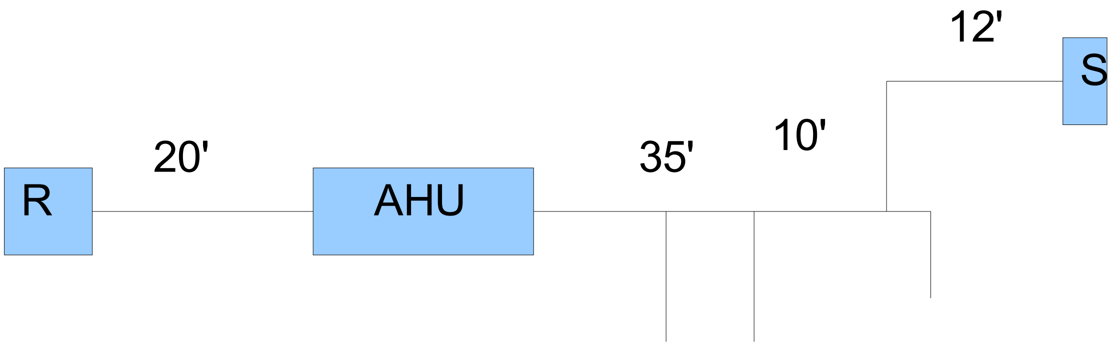
$$\frac{\text{AVAILABLE STATIC PRESSURE x 100}}{\text{TOTAL EFFECTIVE LENGTH}}$$

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 longest distance in the duct system is from return R to Outlet S, 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 and 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. To determine the total equivalent length, we must add the equivalent lengths of each component Example:

From the return to supply outlet S 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 friction rate 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 BTUH furnace. Supply outlets A and B 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 BTUH and the living room load is 7900 BTUH then the percent of load represented by the living room is:

ROOM LOAD PERCENT = **ROOM BTUH** / **WHOLE HOUSE BTUH**

$$= \frac{7900}{58,000}$$

= .136 or 13.6%

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):

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

= 1250 /58,000

= **.0215**

To get the room CFM:

ROOM CFM = HF x ROOM HEAT LOAD

= .0215 x 7900 BTUH

= **170 CFM**

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 quiet duct run.

The duct runs for each of the other rooms are sized just like you sized the living room. Continue to use the same adjusted static pressure of .095. 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 that 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;

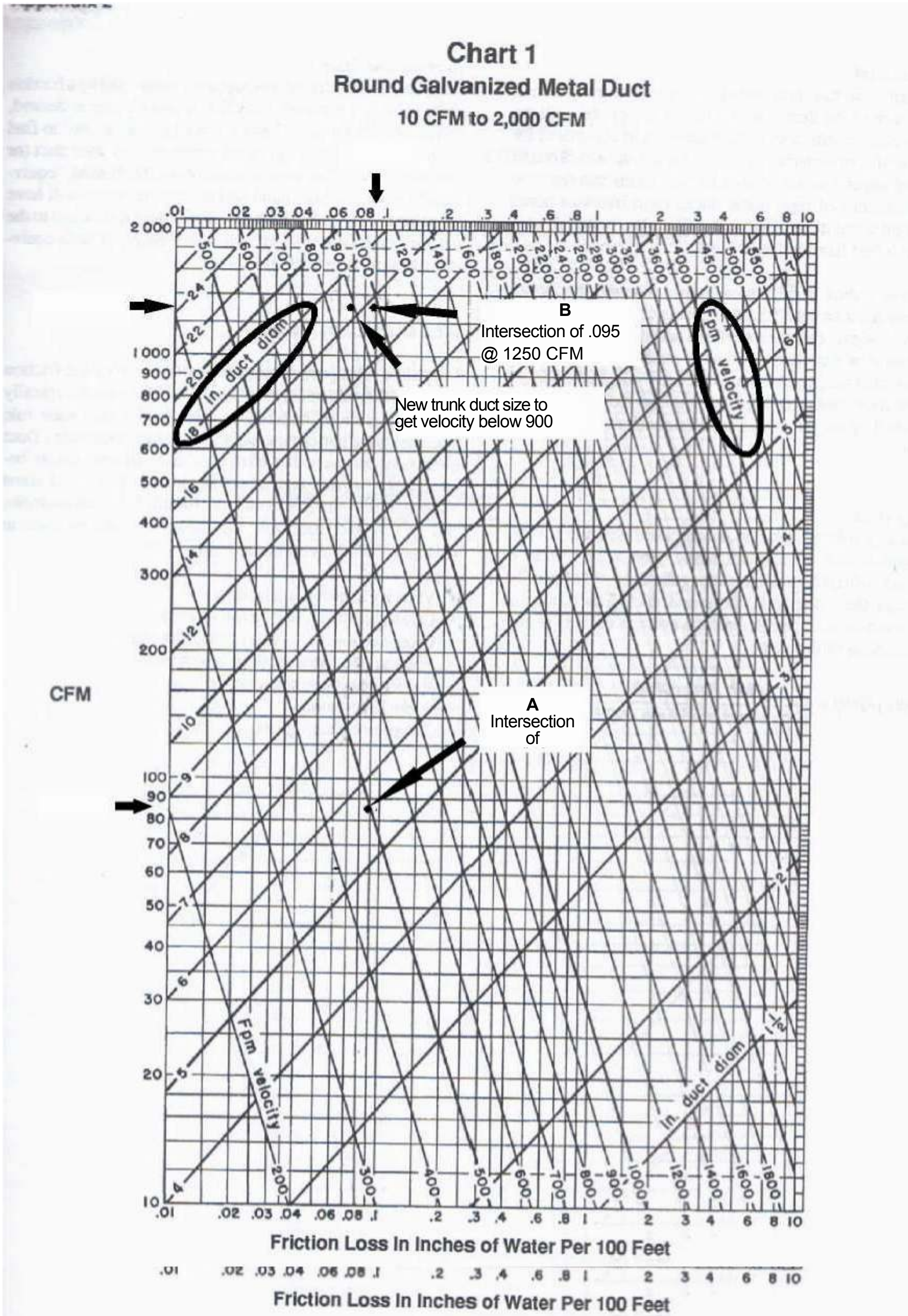
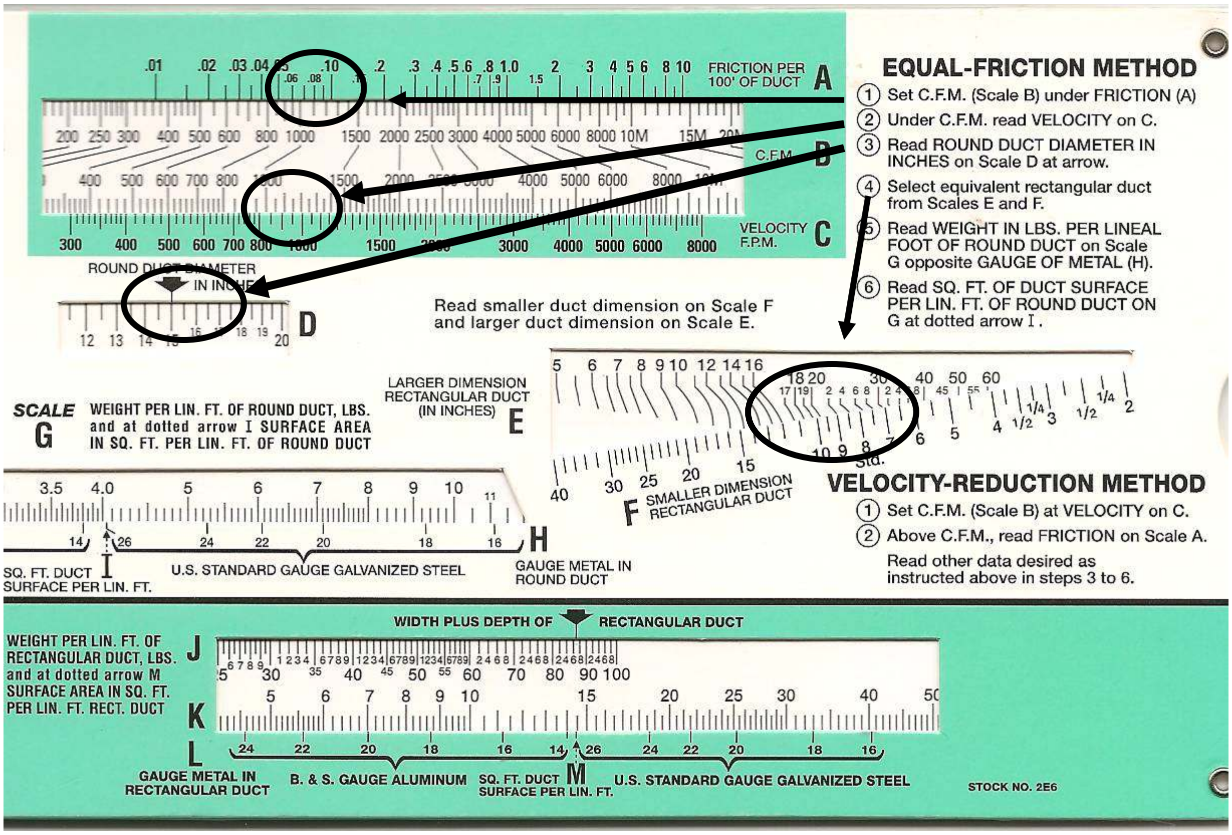


Chart 1
Round Galvanized Metal Duct
10 CFM to 2,000 CFM
B
Intersection of .095
@ 1250 CFM
New trunk duct size to
get velocity below 900
A
Intersection
of
In. duct diam
Fpm velocity
CFM
Friction Loss In Inches of Water Per 100 Feet



Using a duct calculator

All duct calculators work the same, some are round and some are rectangular. Some may give more information than others.

Note: Adjusted static pressure must be calculated before a duct using a duct calculator

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.

Line up *adjusted* static pressure with CFM required for each supply and return trunk and each run. For this example, the supply trunk handles 1250 CFM @ .095 SP. The velocity is approximately 1050 feet/min. The round duct size is 15" and if needed, an 8" x 26" rectangular duct may be used. Since 900 feet/min is the limit for metal supply duct, a 15" round duct will be too small. However, since 15" is not a standard round duct size, we must use 16". Place 16" under the arrow at **D** and you will see the velocity reduced to an acceptable level of about 900 feet/min. on line **C.**

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 the example.
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 3-1/2 ton, 1400 CFM air conditioner in a house having a total <u>sensible</u> heat gain of 33,000 BTUH using the *average load method*). The load for a room facing east is 5500 BTUH and a room facing west is 4200 BTUH. In reality, using the *peak load method*, at 3:00 in the afternoon the room facing east may only require 2500 BTUH because the sun is on the west side of the house at that time of day. Meanwhile, the west facing room would require 7200 BTUH. Both calculation methods show the same heat gain (Total 9500 BTUH) but the ducts must be sized differently. If the average load method is used then the west room's run would be sized to handle 4200 BTUH. If the peak load method (used for zoning) is used, then the room's run would be sized to handle 7200 BTUH

The room peak load CFM; therefore, would be calculated as follows:

COOLING FACTOR (CF) =BLOWER CFM / WHOLE HOUSE LOAD

= 1400 / 33,000

= **.042**

ROOM CFM = CF x ROOM COOLING LOAD

=. 042 x 7200

= 302 CFM

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)

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

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

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

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

= 80,000/(1400 x 1.1)

= **52 degrees**

Question: 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 BTUs

Then apply the above CFM formula

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

= **1107 CFM**

Velocity (feet per minute)

FPM = CFM/AREA (Note: area is in square feet, 1 sq. ft. = 144 sq. ft.)

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

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.

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

= **560 FPM**

Question: If the velocity in the above duct is 650 FPM, what is the CFM?

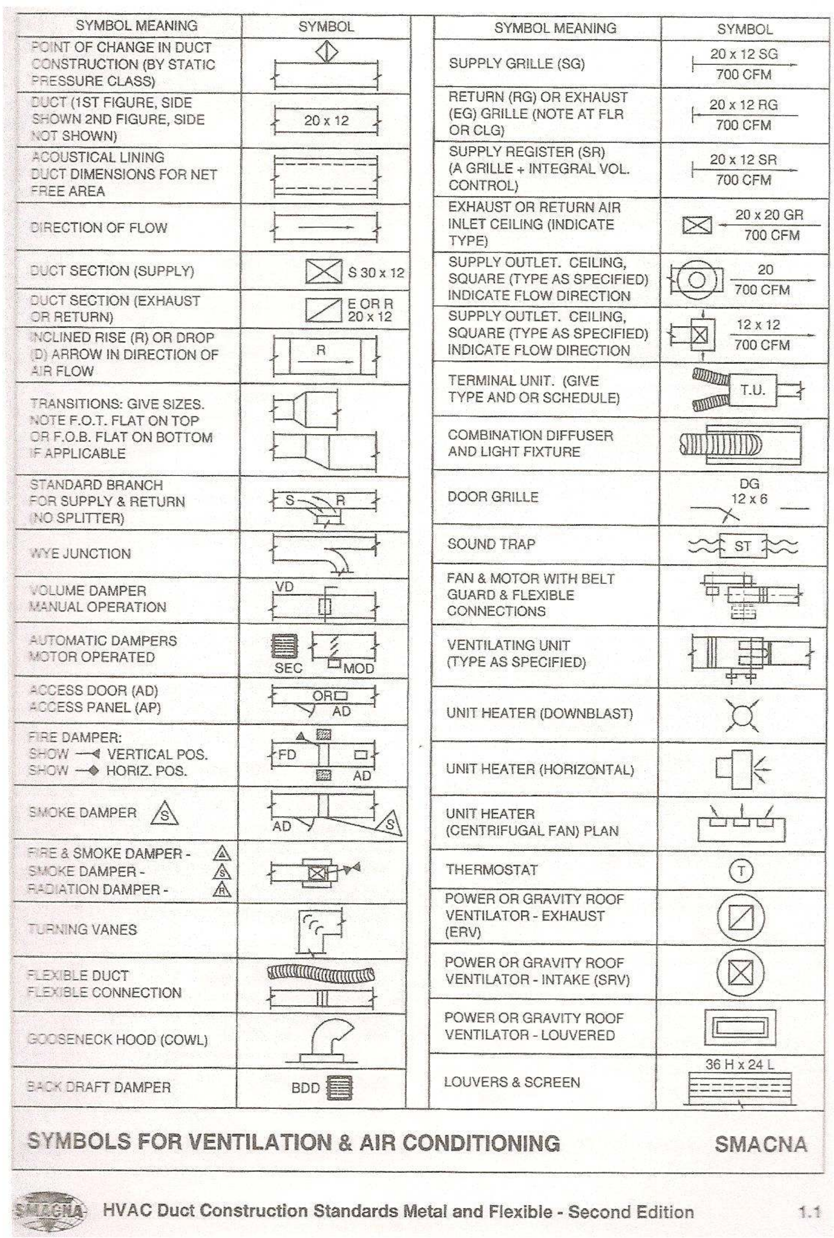
Answer: CFM = FPM x AREA

= 650 x 2.5

= **1625 CFM**

Chapter 5

Symbols and Psychrometrics

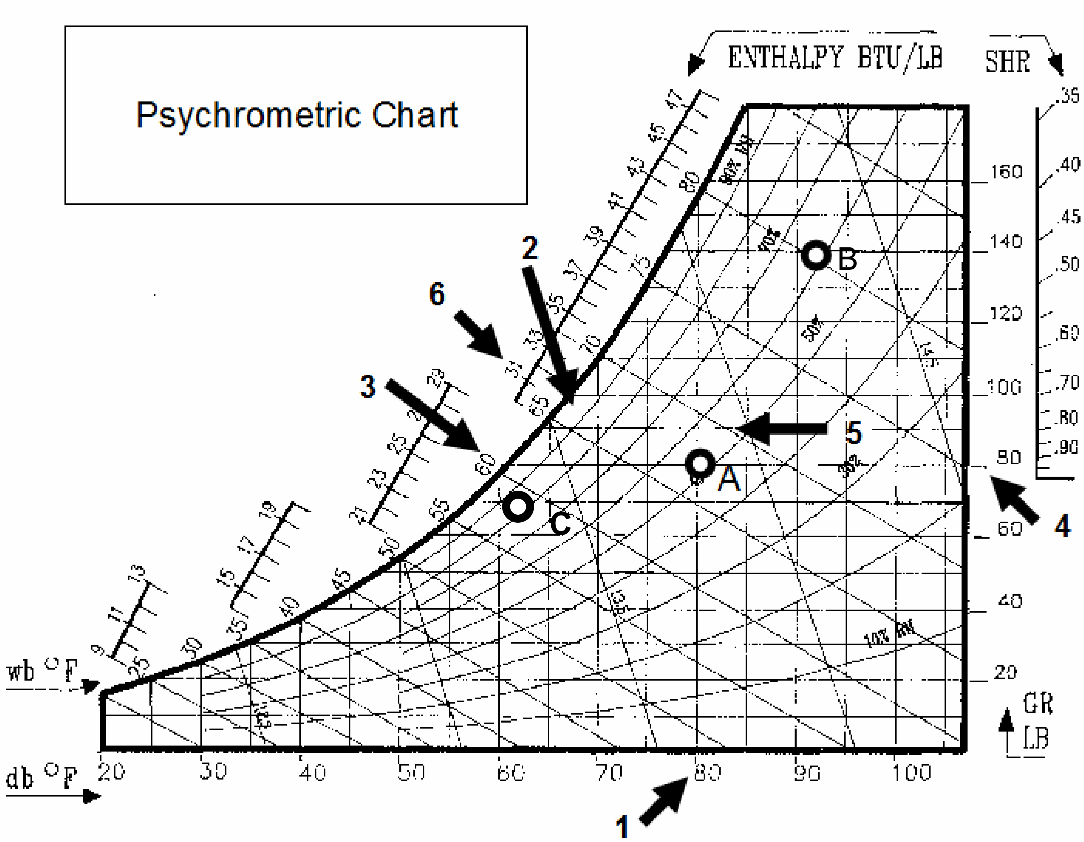


SYMBOL MEANING	SYMBOL	SYMBOL MEANING	SYMBOL
POINT OF CHANGE IN DUCT CONSTRUCTION (BY STATIC PRESSURE CLASS)		SUPPLY GRILLE (SG)	20 x 12 SG 700 CFM
DUCT (1ST FIGURE, SIDE SHOWN 2ND FIGURE, SIDE NOT SHOWN)	20 x 12	RETURN (RG) OR EXHAUST (EG) GRILLE (NOTE AT FLR OR CLG)	20 x 12 RG 700 CFM
ACOUSTICAL LINING DUCT DIMENSIONS FOR NET FREE AREA		SUPPLY REGISTER (SR) (A GRILLE + INTEGRAL VOL. CONTROL)	20 x 12 SR 700 CFM
DIRECTION OF FLOW		EXHAUST OR RETURN AIR INLET CEILING (INDICATE TYPE)	20 x 20 GR 700 CFM
DUCT SECTION (SUPPLY)	S 30 x 12	SUPPLY OUTLET. CEILING, SQUARE (TYPE AS SPECIFIED) INDICATE FLOW DIRECTION	20 700 CFM
DUCT SECTION (EXHAUST OR RETURN)	E OR R 20 x 12	SUPPLY OUTLET. CEILING, SQUARE (TYPE AS SPECIFIED) INDICATE FLOW DIRECTION	12 x 12 700 CFM
INCLINED RISE (R) OR DROP (D) ARROW IN DIRECTION OF AIR FLOW	R	TERMINAL UNIT. (GIVE TYPE AND OR SCHEDULE)	T.U.
TRANSITIONS: GIVE SIZES. NOTE F.O.T. FLAT ON TOP OR F.O.B. FLAT ON BOTTOM IF APPLICABLE		COMBINATION DIFFUSER AND LIGHT FIXTURE	
STANDARD BRANCH FOR SUPPLY & RETURN (NO SPLITTER)	S R	DOOR GRILLE	DG 12 x 6
WYE JUNCTION		SOUND TRAP	ST
VOLUME DAMPER MANUAL OPERATION	VD	FAN & MOTOR WITH BELT GUARD & FLEXIBLE CONNECTIONS	
AUTOMATIC DAMPERS MOTOR OPERATED	SEC MOD	VENTILATING UNIT (TYPE AS SPECIFIED)	
ACCESS DOOR (AD) ACCESS PANEL (AP)	OR AD	UNIT HEATER (DOWNBLAST)	
FIRE DAMPER: SHOW —◄ VERTICAL POS. SHOW —◆ HORIZ. POS.	FD AD	UNIT HEATER (HORIZONTAL)	
SMOKE DAMPER S	AD S	UNIT HEATER (CENTRIFUGAL FAN) PLAN	
FIRE & SMOKE DAMPER - SMOKE DAMPER - RADIATION DAMPER -		THERMOSTAT	T
TURNING VANES		POWER OR GRAVITY ROOF VENTILATOR - EXHAUST (ERV)	
FLEXIBLE DUCT FLEXIBLE CONNECTION		POWER OR GRAVITY ROOF VENTILATOR - INTAKE (SRV)	
GOOSENECK HOOD (COWL)		POWER OR GRAVITY ROOF VENTILATOR - LOUVERED	
BACK DRAFT DAMPER	BDD	LOUVERS & SCREEN	36 H x 24 L

SYMBOLS FOR VENTILATION & AIR CONDITIONING SMACNA

SMACNA HVAC Duct Construction Standards Metal and Flexible - Second Edition 1.1

Psychrometrics



Above is a psychrometric chart which shows the *properties of air*. If you were to place a point anywhere on the chart, you will learn much about the air. Point A tells us the following properties of a sample of indoor air:

1. The dry bulb temperature is 80F (Temp measured with a regular thermometer)

2. The wet bulb temperature is 67F (Temp measured with a wet bulb thermometer)

. The dew point temperature is 60F (Temperature at which condensation appears, any surface 58F or below will become wet)

4. Absolute humidity is 80 grains/lb. (1 lb. of this air will contain 80 grains of moisture, which is the actual amount of moisture in the air)

5. The relative humidity is about 52% (% of moisture in the air compared to amount it can hold, This air sample is holding 80 grains but could hold 154 before becoming saturated)

6. The total enthalpy is 31 btu/lb of air (Total heat content of the air)

Now look at point B, this could represent the outdoor conditions on a typical summer day.

1. What is the dry bulb temperature? _________F
2. What is the wet bulb temperature? ________F
3. What is the relative humidity? ________%
4. What is the dew point temperature? _________F
5. What is the grains difference from indoor and outdoor conditions?___gr

Extra credit - What is the dew point temperature in a room with a dry bulb of 75F and 60% RH?_____F

Answers at bottom of page

Point C is a sample of typical air coming from the supply duct of a three ton air conditioner. Assuming A is the room conditions and C is the condition of the air generated by the air conditioner, we can calculate the capacity of the air conditioner using the following formula:

BTUH= 4.45 x cfm x enthalpy diff.

If the air conditioner is rated at 3 tons, we can assume the cfm is 1200 (400 cfm/ton). Looking at the psych chart, the enthalpy of the indoor air (Point A) is about 31 and the enthalpy of the A/C air (point C) is about 25.5. Therefore the enthalpy difference is 5.5 (31-25.5). Thus:

4.45 x 1200 x 5.5 = 29,370 BTUH

Since the unit is supposed to be supplying 36,000 BTUH it appears our A/C unit is not putting out like it should or there is about a 20% duct loss.

Answers: 1. 92F 2. 75F 3. 85% 4. 57F 5. 60 grains extra credit- 59F

Chapter 6

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 processes started off right, accounting becomes not only easy, it becomes completely logical. Once you see the light you'll wonder why anyone would find accounting difficult. This section 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 states that for every debit there must be a credit (right column) and vice versa, therefore, if Joey 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. **Owner's equity** is your net worth.

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 **journal**. 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 of 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 pays 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 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 and 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 debit 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, 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 arrive, 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 and 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 glue, 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 the 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. Let's 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 the materials account and a credit to accounts payable and the $10 for string will be a debit to the materials account and a credit to cash. Remember, he charged the wood but paid cash for the string.

> Generally, money kept in a drawer, **petty cash**, will have its own account. Joey could have cashed a check at the bank and used it for petty cash. Therefore, the entry would be credit cash and debit a new account called petty cash. The string would then be paid out of petty cash; credit petty cash and debit materials.

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 the sales account (**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.

To keep up with day-to-day transactions, Sally has made the following entries in the **journal**.

GENERAL JOURNAL

Date	Description	Debit	Credit
2/5/2007	cash	2000	
	accounts payable (loan from uncle Bob)		2000
2/7/2007	cash		150
	rent expense	150	
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

Date	Description	Debit	Credit
	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 as 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) or will pay cash later - 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 (total assets-total liabilities)	**$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 you're worth (**owner's 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 the following:

JACKS CRAB OPERATION

INCOME STATEMENT

Dec. 31, 2007

Sales		$32,300	100%
Direct costs	$2250		
Fuel and oil	900		
Bait	480		
Misc. supplies	3630		
Cost of goods sold		$7260	22.5%
Overhead			
Slip rent	700		
Depreciation	8900		
Insurance	320		
Licenses	125		
Repairs	1670		
Interest	1920		
Total overhead		$13,635	42.2%
Total costs and overhead	20,895		64.7%
Income from operations	11,405		35.3%
Other income			
Gain on sale of boat	5200		
Income before taxes	16,605		51.4%
Income taxes	4360		
Net income	$12,245		37.9%

Notice the percentages to the right. Each one represents a percentage of total sales (revenue). For example, overhead equals 42.2% of sales ($13,635/$32,300). When we talk about percentages in business they are generally expressed as percent of sales. When a business person 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

= $12,245/$38,485

= .32 or 32% (this tells Jack he is making the equivalent to 32% interest on his investment)

How to price a job and stay in business

This is perhaps the most important section of this section. 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, 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 guys. 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 a job 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

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

Solution:

6) He knows the material and labor cost per yo-yo is $1.00.
7) Joey's overhead + profit = 27%.
8) 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, give me a 25% discount. After all, you're still making 2%. Try it and 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.

Question: 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:

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

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

Solution:

$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), 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
290	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	52	43	34	25	19	13	7	1	0	0	0

Circular E (for current publication go to **http://www.irs.gov/pub/irs-pdf/p15.pdf**)

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 $113,700 for the year, he will no longer have to pay social security (2013 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)	.0145 x $516 =	7.48
(Federal tax)	see circular E	22.00
(State tax)	.07 x $516 =	36.12

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

Weekly pay	$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 the following:

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 which 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.

Calculating depreciation expense

Most expenses are cut and dry. If you spend $160 on utilities, the expense is $160. Depreciation, on the other hand, must be calculated. Two common methods used to calculate depreciation are the **straight line** and the **accelerated depreciation** method. To illustrate each method we will depreciate a backhoe purchased in July for $19,500.

Under the **straight line method**, $5000 will be estimated to be the **salvage value** (what you think you can sell it for at the end of five years); therefore, $14,500 is to be depreciated evenly throughout a five-year period. In each of the five years you can deduct $2900. Since you purchased the backhoe in July and your *fiscal year* ends in December, you are only entitled to six months depreciation the first year, which is 1/2 year or $1450. The fifth year of ownership will fall on July so you will also get 1/2 of that year's depreciation ($1450).

IRS rules allow for methods of **accelerated depreciation**, which allows a business to claim a higher amount of depreciation for assets in the first years of operation. One such method is the *double declining balance method.* For example; the backhoe above has a life of five years, therefore each year 1/5 or 20% may be depreciated. The double declining balance method allows the business to take 40% (double the 20% allowed under the straight line method above) of the asset balance as depreciation expense each year until its useful life comes to an end.

		Depreciation	Book Value
Year 1	.40 x $19500 =	$7800	balance = $11700
Year 2	.40 x $11700 =	$4680	balance = $7020
Year 3	.40 x $7020 =	$2808	balance = $4212
Etc…..			

What happens if the backhoe is sold after six years for $3500? If, you used the straight line method you will have to show $1500 as *a loss on sale of assets* under other income/expenses on your income statement because the books are showing it is worth $5000. If you used the accelerated depreciation method, $3500 would show up as *a gain in sale of assets* because the books are showing it to be worth $0.

Chapter 7

Administrative Code

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.

Chapter 8

Residential Building Code

2009 code and earlier

Note: If your exam is based on the 2009 codes or later, skip this chapter and go to chapter 9

Almost all test questions pertaining to this code will come from Section 1103. 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 1103.1, Residential Building Code.

Chapter 9

Energy Code

2006 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 and duct and pipe insulation requirements are in the *Residential Building Code*.

Areas of the book to review:

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.

2009 energy code

Almost all questions pertaining to this code will come from section 403 (residential requirements) and 503 (commercial requirements). Tables 502.x.x give minimum efficiencies of equipment. Use these efficiency standards for both residential and commercial equipment.

The highlights are:

R8 duct insulation required for attics, R6 everywhere else.

Automatic setback thermostats required for fossil fuel furnaces (not heat pumps).

heat pump strips not allowed to operate when outdoor temperature is above the balance point.

Minimum R3 refrigerant pipe insulation.

Minimum SEER 13.

Minimum HSPF 7.7.

Duct sealing and air leakage test required for all ducts in unconditioned areas.

It is best to read over Section 503 to familiarize yourself with the requirements for commercial HVAC equipment.

Chapter 10

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.

Section 303.5

Fuel fired furnaces installed in closets or alcoves must be *listed* for such installations.

According to Section 303.5, a furnace measuring 24" wide x 34" deep x 54" high is installed is an enclosure, measuring 4' wide x 5' deep with 9' ceilings. Is the enclosure a *room* or a *closet*

Answer: *Closet*. If the enclosure is less than 12 times the volume of the furnace, then it is a closet.

4 ft x 5 ft. x 8 ft. = 160 cubic ft (volume of room) Note: although the ceiling is 9 ft. high, code say limit it to 8 ft.

24 in. x 34 in. x 54 in. = 44064 cubic in.

44064 cu. in. / 1728 = 25.5 cubic ft. (1728 cu. in = 1 cubic ft., 12" x 12" x 12")

160 cubic ft. / 25.5 = **6.27 times**

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 5.

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

Answer: 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**

5CFM is required for each person

5 x 75 = **375 CFM**

Section 502 Dry cleaning operation

How many cfm must be exhausted for a 2200 sq. ft. dry cleaning room using Type II solvent?

Answer: 1 cfm per sq. ft. *or* 1 X 2200 sq. ft. = 2200 cfm

Domestic clothes dryers (504.6)

Question: According to the requirements of the code, is a 30 ft., 4" diameter, rigid dryer vent with two 90-degree bends allowed?

Answer: No. The section states that the maximum length cannot exceed 35 ft., minus 5 ft. for each 90 degree bend . Therefore, 25 ft. is the longest the vent is allowed (+35 - 5 -5 = 25ft.). .

Medium-duty cooking appliance exhaust hood (507.13.3)

Question: 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) Question: May a 16" x 20" return air grille with 75% free area be used on an 80,000 btuh, 80% AFUE furnace?

   Answer: YES

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

   Output of furnace is 80,000 btuh x .80 = 64,000 btuh

   Section 918 says return must equal minimum 2 sq. in. per 1000 btuh *output*. Therefore, 64,000/1000 = 64

   64 x 2 sq. in. = 128 sq. in.

   The grille has 240 sq. in free area, while only 128 sq. in. are needed.

Chapter 11

Fuel Gas Code

Combustion air requirements

Section 304.5

Question: According to section 304.5, **If the infiltration rate is unknown**, does a room measuring 10' x 10' x 8' high with two 60,000 BTUH furnaces require outdoor air for combustion?

Answer: Yes. The volume is less than 50 cu. ft. per 1000 BTUH

Solution: Divide the total BTUH by 1000

120,000/1000 = 120 (1000's)

Then multiply the number of 1000's by 50 cubic ft.

120 x 50 =6000

If the room is less than 6000 cu. ft., then it needs combustion air. If it is more than 6000 cu. ft. no additional combustion air is required.

The room is 10' x 10' x 8' = 800 cu. ft.; therefore, additional combustion air is required

If the **infiltration rate is known,** the following formula <u>may</u> be used in lieu of the above to determine the minimum volume needed without having to add outside air. However, if the infiltration rate is know to be less than .40 air changes per hour, then the following formula <u>must</u> be used.

Question: An area measuring 20 ft. x 30 ft. x 9 ft. is being heated by a 45,000 btuh fan assisted furnace. If the infiltration rate is .35 air changes per hour, is additional combustion air needed?

For fan assisted appliances (most 80+ AFUE furnaces), the

required volume must be greater than:

(15 cu. ft/ .35) x (45,000/ 1000 btuh) =

42.857 x 45 = **1928 cubic feet**

The building is: 20 ft. x 30 ft. x 9 ft. = 5400 cubic feet

Therefore, no additional outdoor air is required for this building.

Section 304 Combustion air

Question: 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

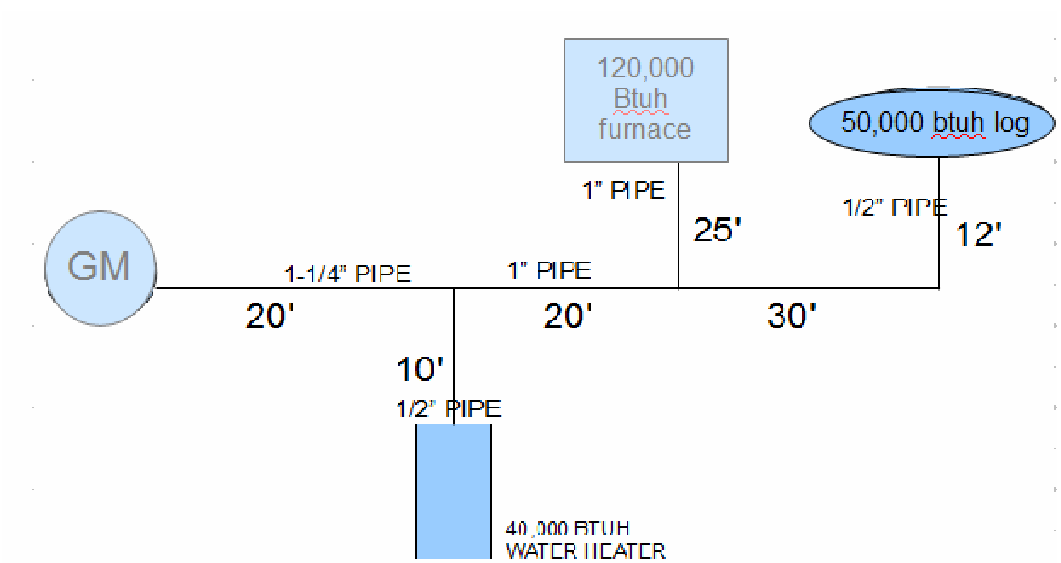
Gas Pipe Sizing

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 methodology 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**

<u>all</u> pipe using this row. The number 13 directly to the right of 90 means a 1/4" schedule 40 metallic pipe will handle 13,000 BTUs (approx. 1000 BTUs/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 430,000 BTUH).

After dropping off the water heater load, the next 20' must handle 170,000 BTUH.

Thus the pipe must be 1" (good for 205,000 BTUH).

After dropping off the furnace, the remaining 42' must only handle the gas log, 50,000 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 1/2" (good for 53,000 BTUH). 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 (Not B Vent)</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 B vent is needed for a 160,000 BTUH, 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 150,000 BTUH, while a 6" vent will handle 225,000 BTUH, 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 the **connectors** and the lower section is for sizing the common **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 shorter 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 the 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.

Note section 504.2 Vent offsets

This section states the capacities in the tables allow for no offsets (elbows) in single appliance vents with 0 laterals or two elbows for vents with laterals. If additional offsets are placed in the vent then the capacities must be reduced by 5% for each 45 degree elbow and 10% for each 90 degree elbow.

Example: Using Table 504.2 (1), a 10 foot vent with two offsets (laterals), 2 foot each, would have a total lateral of 4 feet. A 3 inch diameter vent, venting a NAT appliance is good for 57,000 btuh with a 5 foot lateral. However, since this vent has a second lateral which consists of two extra 90 degree elbows, the capacity must be reduced by 20% (10% x 2). Therefore the vent capacity will be reduced to 45,600 btuh (57,000 x .80)

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

Appendix A

Exam Practice Questions

These questions where prepared by Energy Marketing Services to give examples of the types of questions that are found on the HVAC licensing exam. They are only a representation of questions found on the exam, not actual questions.

Carefully read each question and then circle the letter of the best answer.

1) A licensee may have his license revoked for which of the following?

a. Misconduct

b. Gross negligence

c. Incompetence

d. Any of the above

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 contractor 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 refrigerant line insulation for a 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) is 30 feet, 20 feet further down the line is a furnace (120,000 BTUH). 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 .07. What is the new R value if 19 is 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 temperature rise of 45 degrees. What is the CFM?

a. 1212

b. 1667

c. 1515

d. 1175

10) A customer moves up from an 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. Programmable 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 exceeding 15 minutes.

d. A fossil fuel kit.

12) In a room that is large in comparison with the size of equipment, an appliance that requires 18" clearance on its sides may have its clearance reduced to ____ if .024 sheet metal 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 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 horizontal length of a category I appliance vent connector is ______ feet for each inch of its 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 height 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" x 1 0"

b. 3.5" x 1 0"

c. 14" x 10"

d. 8.5" x 10"

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 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 equipped 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 except:

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 purity 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. Clogged 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), 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 rectangular equivalent of _____.

a. 14 x 8

b. 15 x 8

c. 16 x 8

d. 17 x 8

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. 500 FPM

c. 750 FPM

d. 900 FPM

29) All that changes when converting from a round duct to an equivalent rectangle duct is _____.

a. Velocity

b. Static pressure

c. Area

d. CFM

30) For a building to be maintained at 70 F, how many BTUH are required to offset 300 CFM of a 20 F 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 more employees?

a. 10

b. 15

c. 25

d. 50

Answer Key

1. D
2. A - $75,000 = $500,000
   .15
3. D - $750.00 cost
   52.50 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. Table A4-3 (R-values of common building materials), Manual J8, No. 2d indicates the R value for a non-reflective surface is .68 (there are two surfaces, one on each side of partition). Between the gypsum is a 3.5" air space (no insulation), No. 3a with an R value of .94. The 1/2" gypsum, No. 4a has an R value of .45 (there are 2 pieces of gypsum , 1 on each 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 x TD

   TD = BTU/1.1 x CFM

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

   CFM = 60,000 / (1.1 x 45)

   = 60,000/49.5

   = 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, you have the following results:

    360 sq. inches/144 sq. inched per sq. ft. = 2.5 sq. ft.

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

    Duct-u-lators usually give the wrong answer (our duct-u-lator shows 640 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 states 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

140,000 BTUH/2000 BTU =70 sq. inches

2000

A 10" x 7" duct = 70 sq. inches

19.D

<u>1,000,000 = 7.14 gals.</u>

140,000

The oil furnace is 80% efficient, therefore:

<u>7.14 gals.</u> = 8.925 gals.

. 80

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

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

= .36x100

375

= 36

375

= .096 (.10,rounded up)

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 the 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 = CFM x 1.1 x TD

= 300 x 1.1 x (70-20) = 300 x 1.1 x 50

= **16,500 BTUH**

31.B – Business Project Management for Contractors,