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?
1) What is the adjusted static pressure or *friction rate*?
2) 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 =

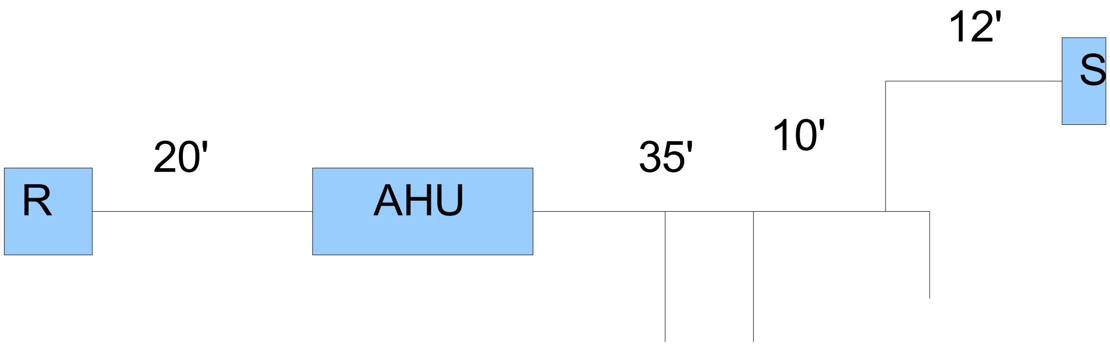
$$\frac{\text{AVAILABLE STATIC PRESSURE x 100}}{\text{TOTAL EFFECTIVE LENGTH}}$$

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

= 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):

HEATING FACTOR (HF) = BLOWER CFM / 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.

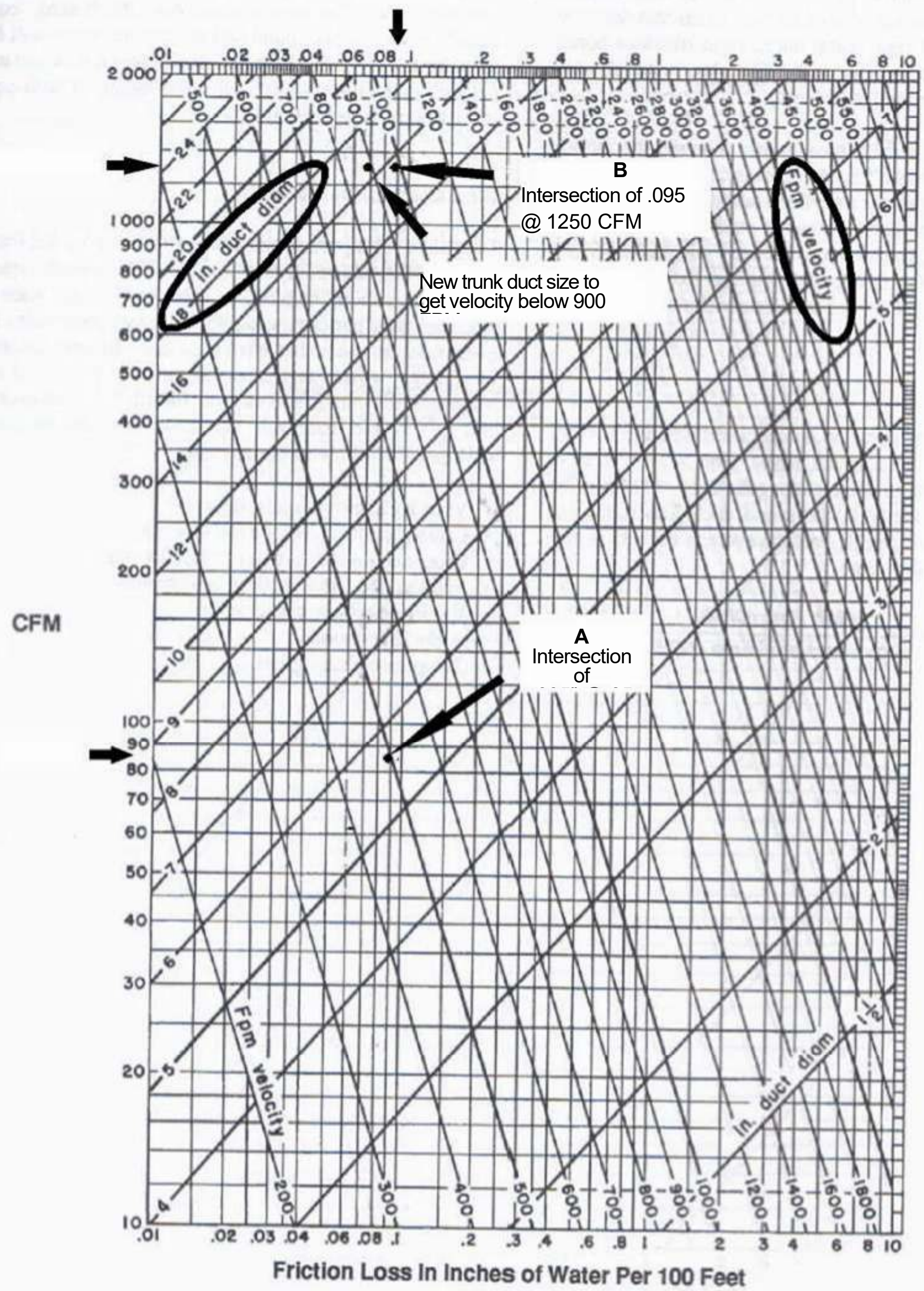
Sizing the supply and return ducts

Assume 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 of the supply 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 remaining 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



.01 .02 .03 .04 .06 .08 .1 .2 .3 .4 .6 .8 1 2 3 4 6 8 10

Friction Loss In Inches of Water Per 100 Feet

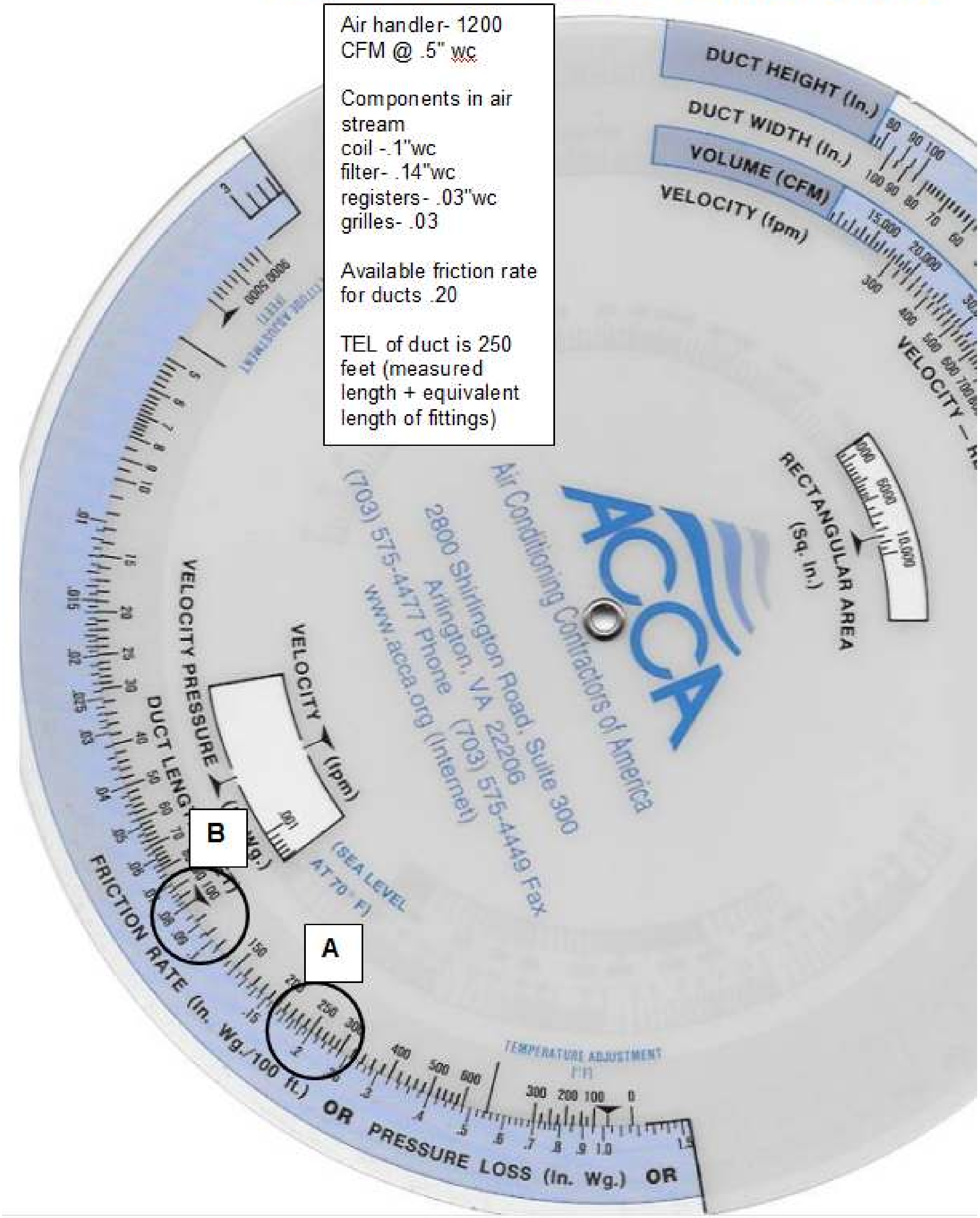
AUXILIARY CALCULATIONS

Air handler- 1200 CFM @ .5" wc

Components in air stream
coil -.1"wc
filter- .14"wc
registers- .03"wc
grilles- .03

Available friction rate for ducts .20

TEL of duct is 250 feet (measured length + equivalent length of fittings)



Using a Duct Calculator (ACCA)

1. Determine the friction rate
   Using the manufactures specs this air handler will deliver 1200 CFM at a pressure of .5"wc.. After subtracting the air side components, we have an *available pressure* of **.20"wc** to build the duct system on.
2. Determine the *total effective length* (TEL) of the duct.
   The measured length is 75 feet and the equivalent length of the bends and fittings is 175 feet. The TEL is 75 + 175 = **250 feet**
3. Line up the TEL with the available pressure (**A**)
4. Read the *friction rate /100 feet* (**B**). In this case the *friction rate* will be .08"wc.
   This is the friction rate you will use to size the duct work.

Assume we are using metal duct for this example

5. Using the other side of the calculator, line up the friction rate, .08 with the air handler volume, 1200 CFM (**C**).
6. Read round duct size in window (**D**). Reads approximately 15.5"
7. To convert the round duct size to rectangular duct use window (**E**).
   First, decide the dimension of one side. For illustrative purpose, lets say one side will be 10". Then looking where the curved line intersects with 10" it appears to be about 20"
8. To determine the velocity (FPM), look at window (**F**). Locate the volume of 1200 CFM and read the velocity below. Approximately 920 FPM

Determine the duct size for a run to a room
   Assume a room requires 150 CFM.
   Line up the friction rate of .08 with the volume of 150 CFM and read the round duct size. It should show about 7"

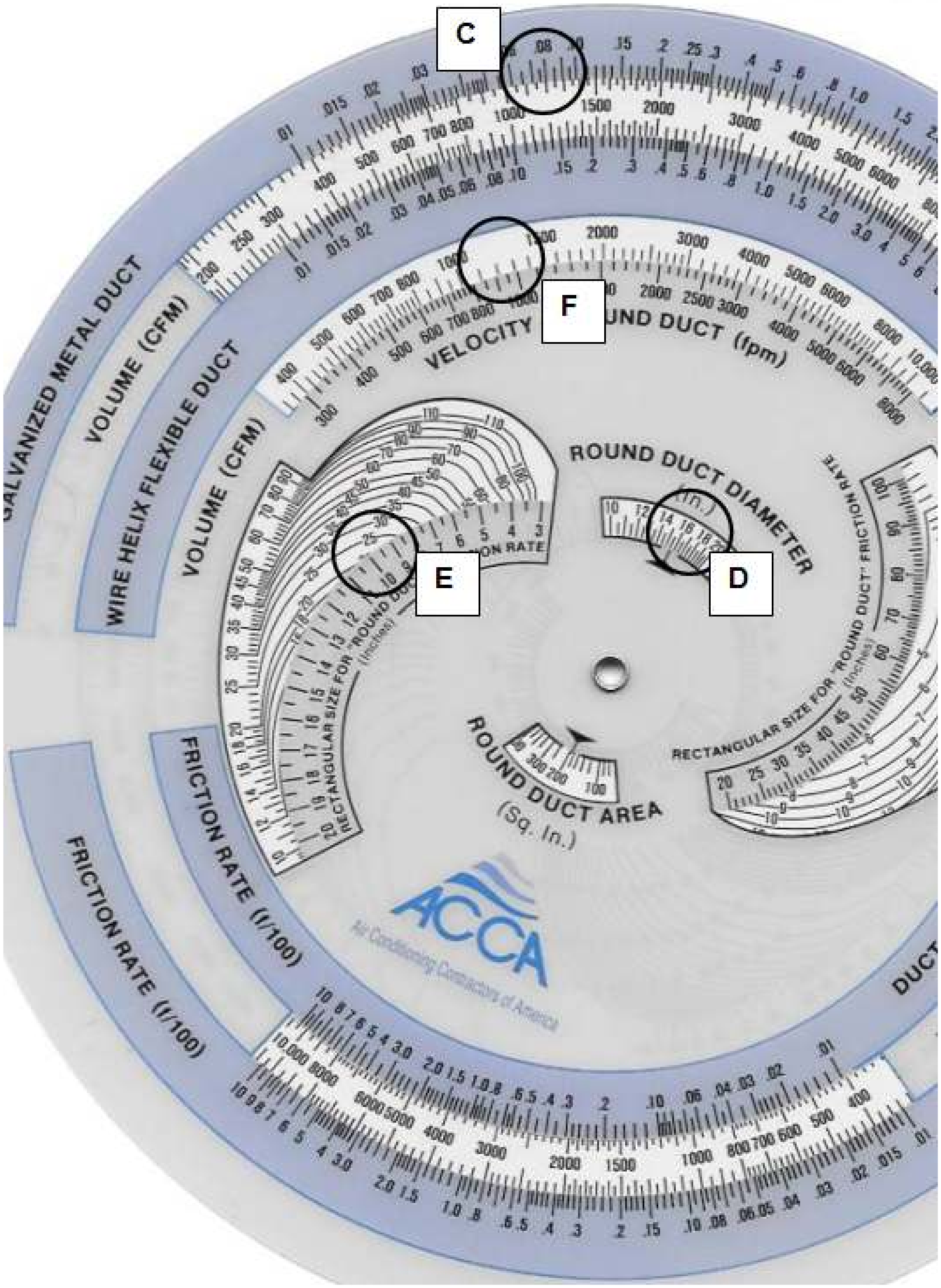
If you are mathematically inclined, you may find it easier to use the following formulas, in lieu of using a duct calculator.

friction rate = available static pressure x 100/ TEL
= .20 x (100 / 250)
= .08

velocity = CFM / Area
= 1200 / 1.31
= **916 FPM**

Area in Sq. Ft.= (3.14 x R x R)/144
= 188.6 / 144
= 1.31 sq. ft.

DUCT SIZING CALCULATIO



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 = BTU

CFM x 1.1

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

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

= 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

= $\frac{51,159}{42 \text{ x } 1.1}$

= **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**