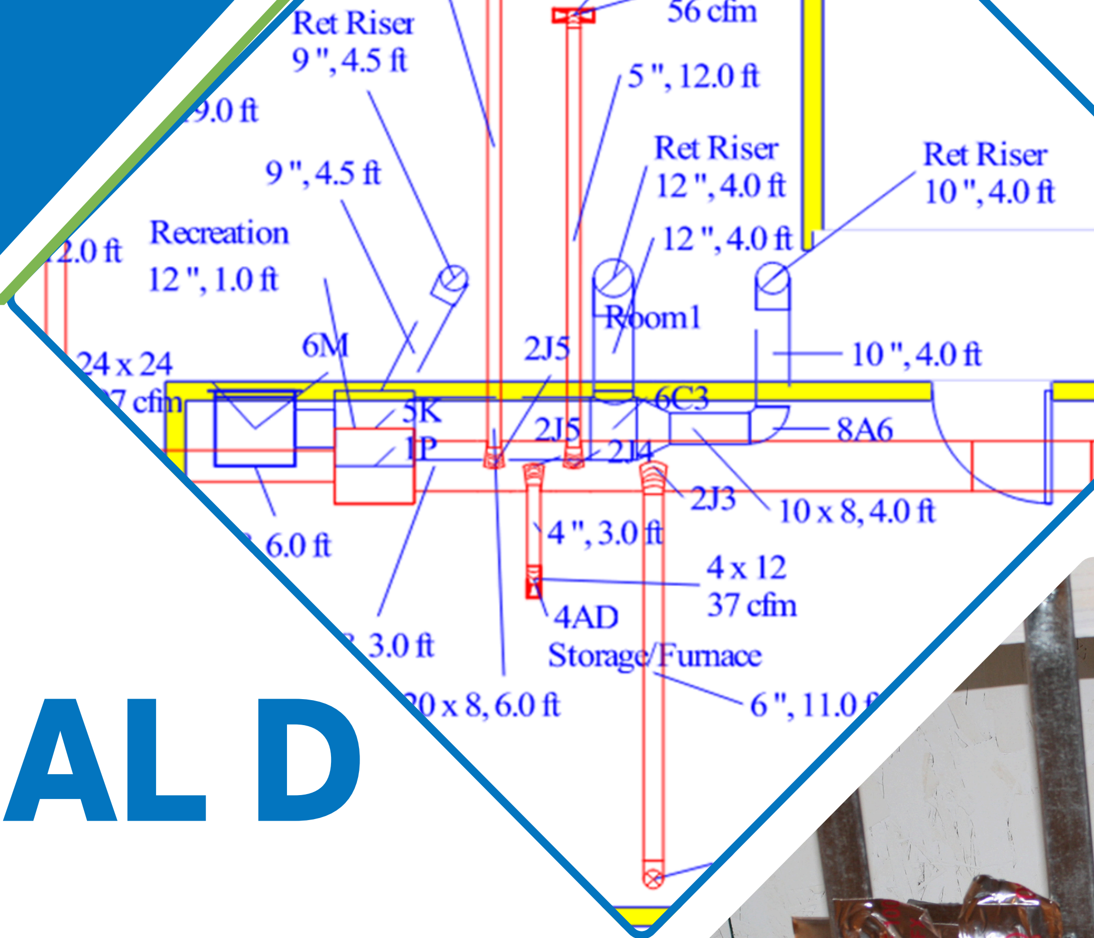
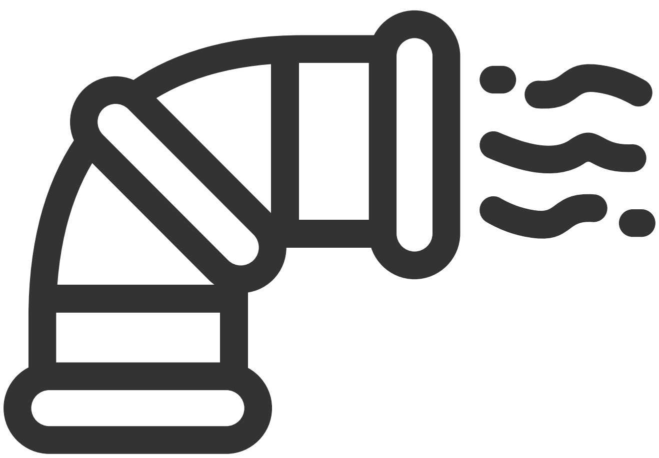
Xcel Energy®



MANUAL D FOR DESIGNERS



SHUMS CODA ASSOCIATES

Group14 ENGINEERING

BUILDTank inc.

This document provides a simple duct design example and outlines the calculations required to determine the duct friction rate and duct size based on the required CFM.

There are several ACCA (Air Conditioning Contractors of America)–approved Manual D software programs available. However, there is no code requirement to use software for duct design. The codes simply require that you follow the Manual D design process to size ductwork properly.

ACCA provides a free Manual D speed sheet, available at:
https://www.acca.org/viewdocument/acca-speed-sheet-for-manual-d

Using the ACCA Manual D speed sheet is an approved method for duct design and is acceptable for submission to jurisdictions during plan review.

Before an accurate duct design can be completed, an accurate Manual J (load calculation) and Manual S (equipment selection) must be performed.

Manual D provides us with design parameters and calculations that will result in a duct system that will provide adequate air flows to rooms. Not designing your ductwork at this stage can have disastrous results like:

- Undersized ductwork affects the furnace temperature rise (to high)
- Undersized ductwork affects the cooling capacity (freezing coil)
- Equipment efficiency is lessened – more energy is used, and comfort levels go down
- Unacceptable noise levels

Manual D requires that the duct system be equipped with balancing dampers. Manual D will get you close but is not perfect. Some duct oversizing will occur; with balancing dampers the flow can be adjusted.

How many contractors use balancing dampers on their systems??
Very few, this is not horrible, but the builder may have some comfort issues.

Steps in Duct Design:

1. Determine cfm flow to each room

2. Make a rough sketch of duct runs- supplies and returns

- It is recommended to sketch directly on the framing plan to avoid structural members.

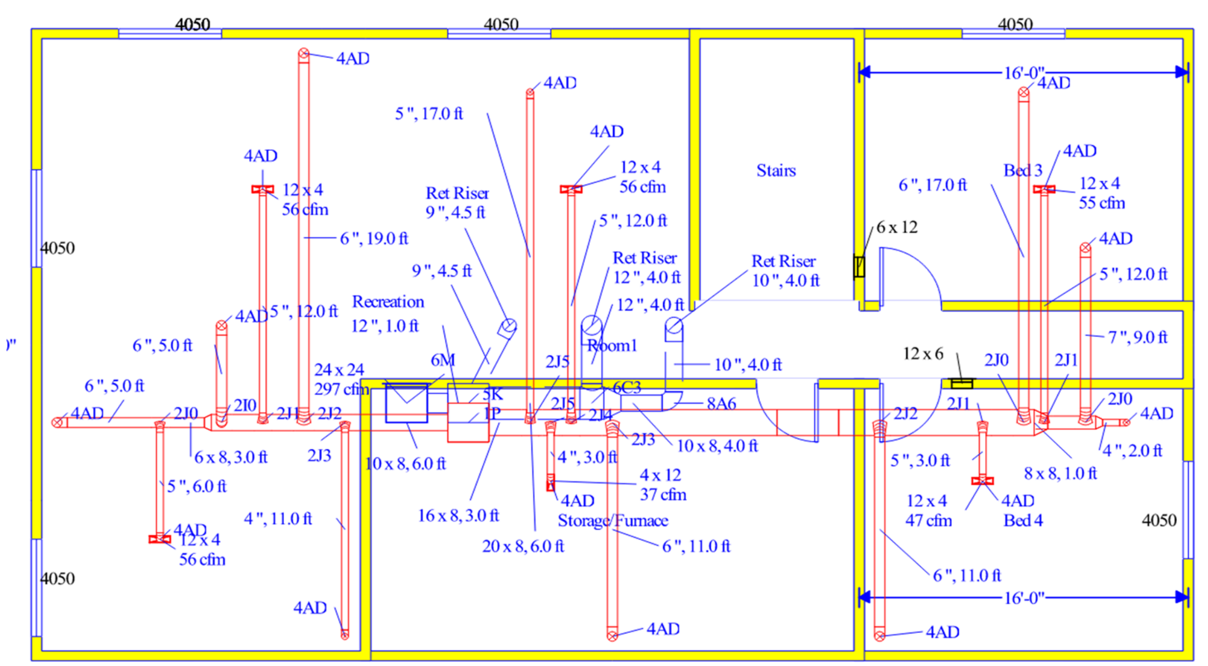
3. Collect information on the blower and all air side pressure drops This would be the coil, air filters, registers and grills

4. Determine the total equivalent length of the duct work

- This is the longest supply path plus the longest return path
- Don't forget the fittings

5. Determine the friction rate. You will need to know available static pressure for this calculation

6. Size all ductwork based on the design flow and friction rate



An accurately designed system will generally perform within these parameters:

1. Total system flow will be ± 5% of design flow

2. Room flows will be ± 10% of design flow. (± 20% can be permitted as permitted)

3. Total system static will be ± 0.10 IWC of design

4. Duct velocities are within Manual D recommendations

Recommended Velocities (FPM)								
	Supply Side				Return Side			
	Recommended		Maximum		Recommended		Maximum	
	Rigid	Flex	Rigid	Flex	Rigid	Flex	Rigid	Flex
Trunk Ducts	700	600	900	700	600	600	700	700
Branch Ducts	600	600	900	700	400	400	700	700
Supply Outlet Face Velocity	Size for throw		700		-------		--------	
Return Grille Face Velocity	--------		--------		-------		500	
Filter Grille Face Velocity	--------		---------		-------		300	

Copy of Table 3-1 from ACCA Manual D

ACCA Friction Rate Worksheet Example

(For use with explanation on the next page)

Friction Rate Worksheet

Step 1) Manufacturer's Blower Data

External static pressure (ESP) = 0.7 IWC Cfm = 600

Step 2) Component Pressure Losses (CPL)

Direct expansion refrigerant coil	0.25
Electric resistance heating coil	
Hot water coil	
Heat exchanger	
Low efficiency filter	
High or mid-efficiency filter	0.1
Electronic filter	
Humidifier	
Supply outlet	0.03
Return grille	0.03
Balancing damper	0.03
UV lights or other component	
Total component losses (CPL)	0.44 IWC

Step 3) Available Static Pressure (ASP)

ASP = (ESP - CPL) = (0.7 - 0.44) = 0.26 IWC

Step 4) Total Effective Length (TEL)

Supply-side TEL + Return-side TEL = (______ + ______) = ______ Feet

Step 5) Friction Rate Design Value (FR)

FR value from friction rate chart = ______ IWC/100

Understanding the Friction Rate Worksheet

The friction rate worksheet is intended to show all components in the system that restrict or inhibit airflow. Each component is represented as a friction loss measured in inches of water column.

The blower information (0.7 external static pressure and 600 CFM) comes directly from the manufacturer's blower performance chart.

The refrigerant coil friction loss also comes from manufacturer data.

It is recommended to include at least 0.1 inches of water column for the filter. Many blower charts assume a "standard" filter during testing, but these filters are often not the higher-efficiency filters used in real installations. Adding a minimum of 0.1 provides a more realistic value.

A friction loss of 0.03 inches of water column for supply registers, return grilles, and balancing dampers is a reasonable general number. Although ACCA Manual T is not required by code, it is strongly recommended to determine the actual friction loss for the specific supply registers and return grilles selected for the project.

The total component loss is the sum of all these individual losses. In this example, the total is 0.44 inches of water column.

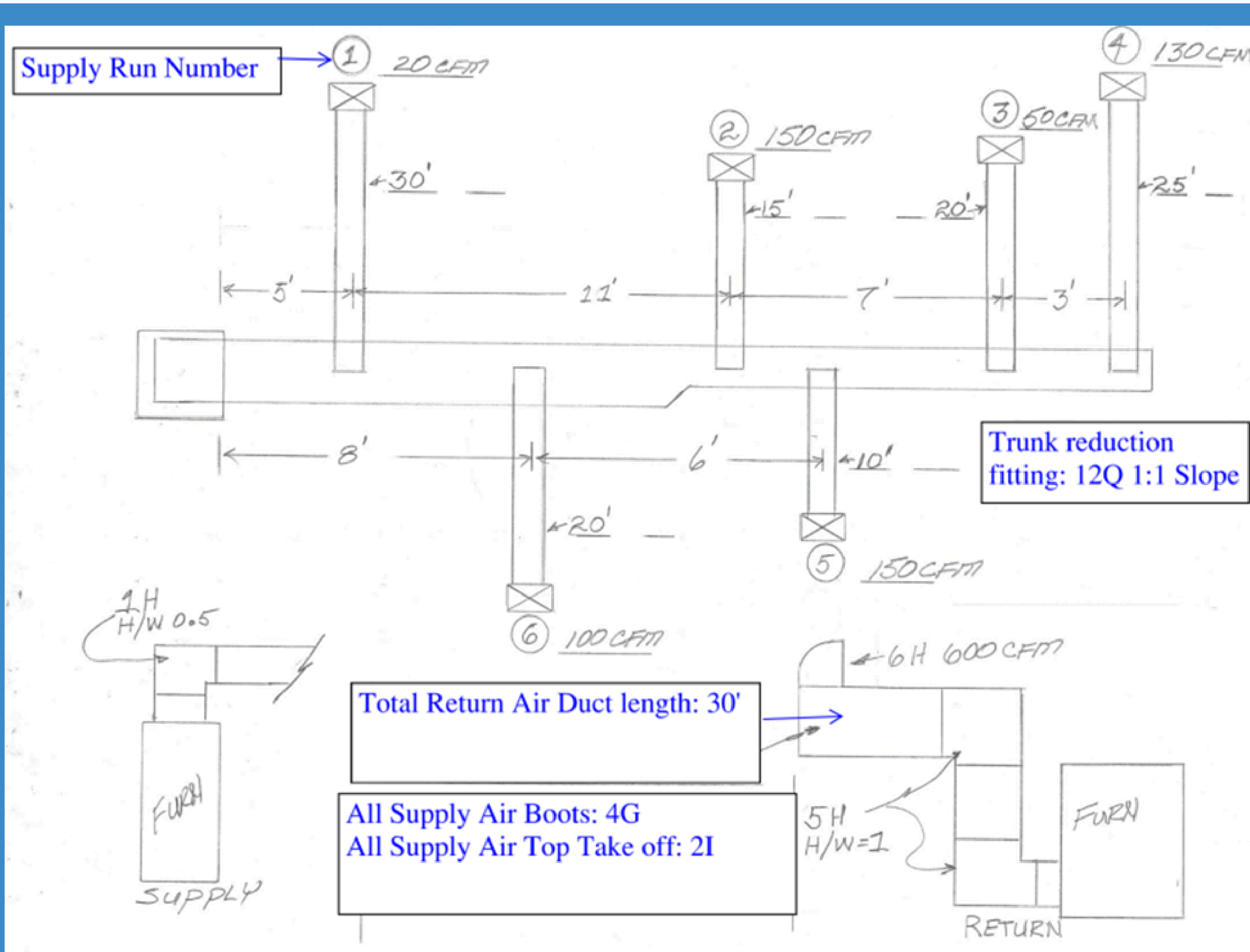
To calculate the available static pressure, subtract the total component losses from the equipment's external static pressure rating. Using the example values:

Total external static pressure − Total component losses = Available static pressure
0.70 − 0.44 = 0.26 inches of water column

This 0.26 inches of water column is the value used for the duct design.

Before we were able to complete our friction rate worksheet we must first calculate our total equivalent length of our duct work. This will be the longest supply duct plus the longest return duct.

EXAMPLE DUCT PLAN



We will use this sheet to identify the longest return and the longest supply ducting.

Effective Length Worksheet

Element	Supply Run ID Number				Element	Return Run ID Number			
						R1			
Trunk Length					Trunk Length	30'			
Trunk Length					Trunk Length				
Trunk Length					Trunk Length				
Runout Length					Runout Length				
Group 1					Group 5 2*45	90'			
Group 2					Group 6	15'			
Group 3					Group 7				
Group 4					Group 8				
Group 8					Group 10				
Group 9					Group 11				
Group 11					Group 12				
Group 12					Group 13				
Group 13					Other				
Other					Other				
Total Length					Total Length	135 '			

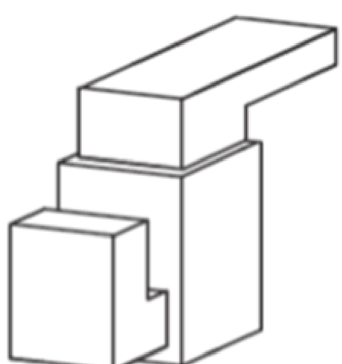
In the example duct design, we only have one return air duct system. We will start with the return system We have labeled the system R-1 and entered the linier footage of the duct system at 30'.

We need to add the equivalent length of the fittings.

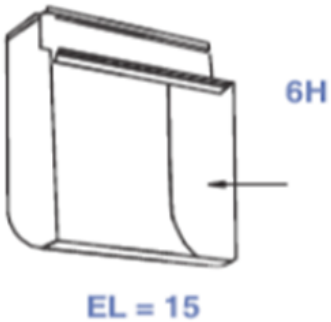
Manual D contains (as does the speed sheet) all fittings and their equivalent length.

FROM MANUAL D

The **5H** with a H/W (Height divided by Width) ratio of 1 has an equivalent length of 45'. Yes the air thinks this fitting is 45' long. As there are two fittings = 90'



Square Elbow 5H	H / W	EL
	1	45
	2	30



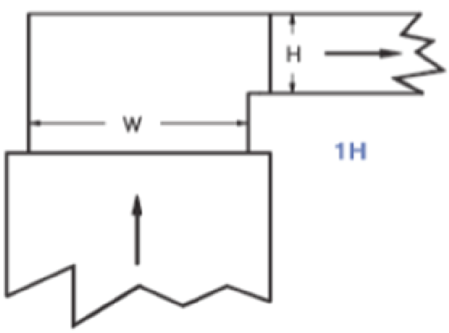
FROM MANUAL D

The return air register fitting has an equivalent length of 15'.

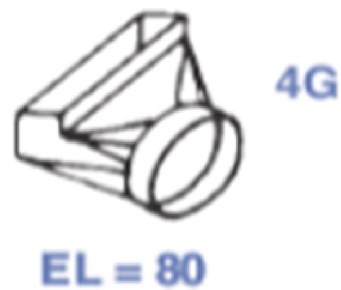
This gives us a total equivalent return duct system length of 135'.

The supply duct system will use the same method. First we will enter the fittings that are common to each of the supply runs. This would be the furnace fitting **1H** H/W 0.5 and the supply boots **4G.**

FROM MANUAL D



No Vanes 1H	H / W	EL
	0.5	120
	1.0	85



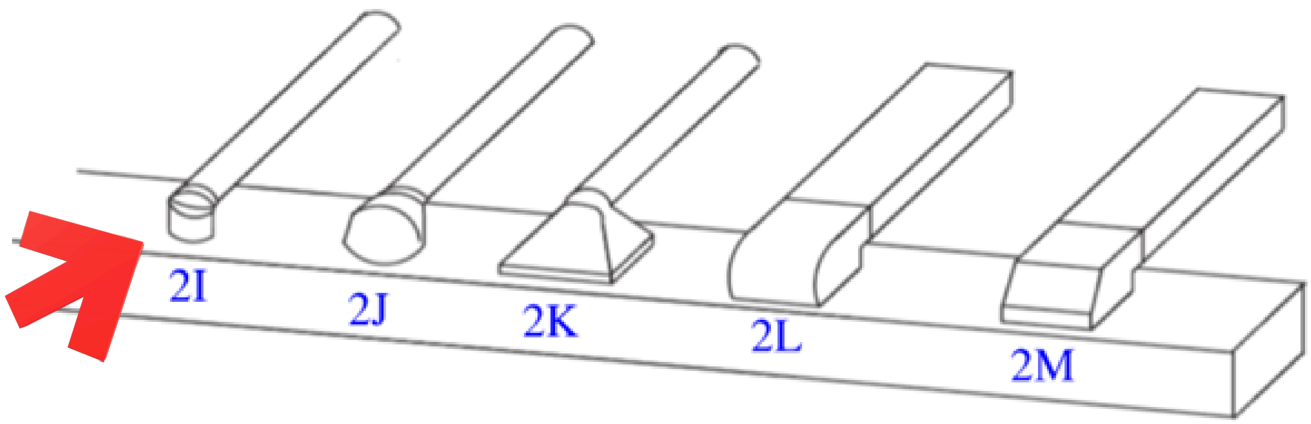
Effective Length Worksheet

Element	Supply Run ID Number				Element	Return Run ID Number			
						R1			
Trunk Length					Trunk Length	30'			
Trunk Length					Trunk Length				
Trunk Length					Trunk Length				
Runout Length					Runout Length				
Group 1	120'	120'	120'	120'	Group 5 2*45	90'			
Group 2					Group 6	15'			
Group 3					Group 7				
Group 4	80'	80'	80'	80'	Group 8				
Group 8					Group 10				
Group 9					Group 11				
Group 11					Group 12				
Group 12					Group 13				
Group 13					Other				
Other					Other				
Total Length					Total Length	135'			

Now looking at the duct design what would be your best guess on which is the longest. Typically, you would look at the three most likely and do the calculation. Before your guess look at supply runs 1 and 2.

Let's look at the duct fitting **2I**

FROM MANUAL D

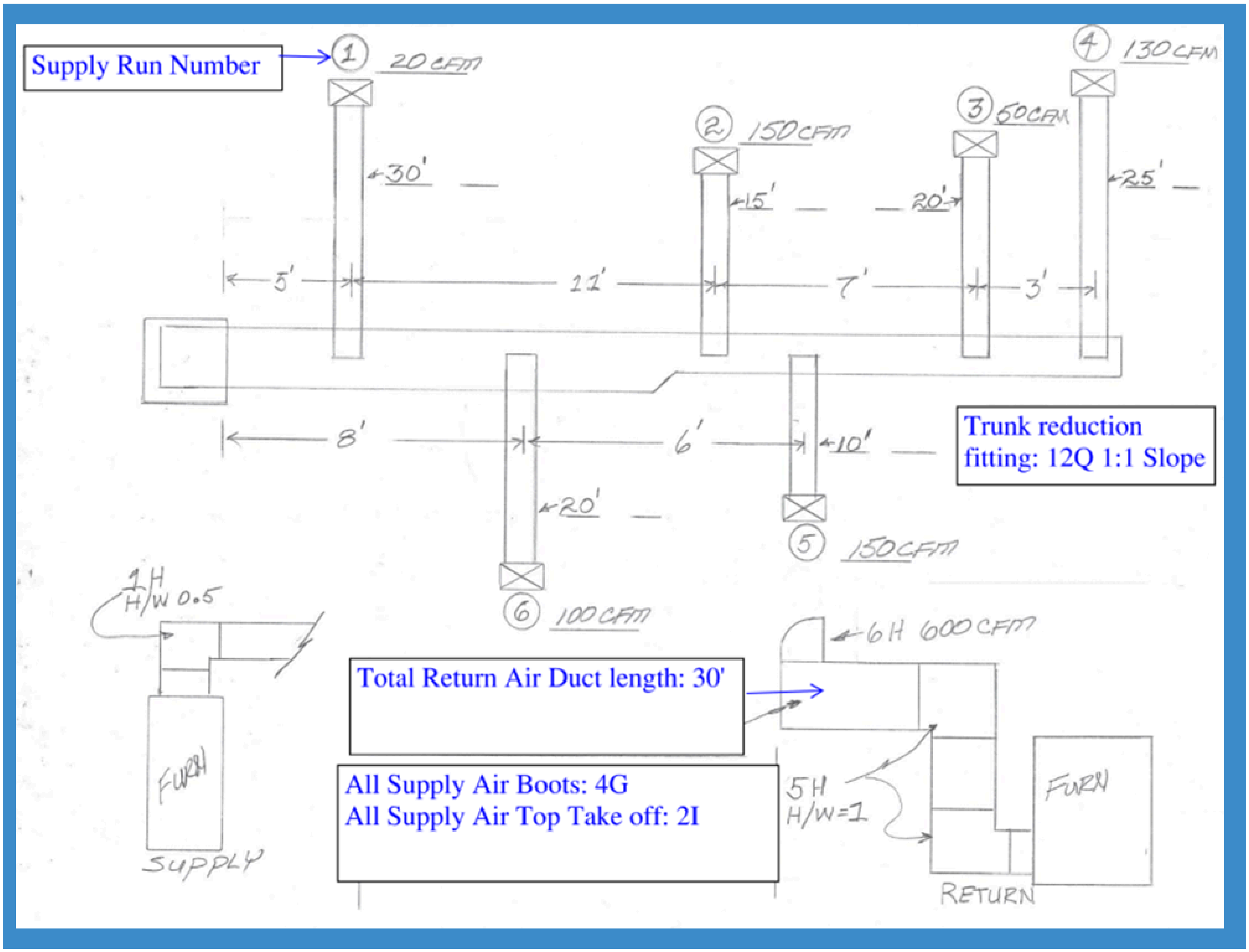


EL Values		Number of Downstream Branches to End of Trunk Duct or Number of Downstream Branches to a Trunk Reducer					
Fitting		0	1	2	3	4	5 or More
	2I	65	75	85	95	100	110
	2J	50	60	65	70	75	80
	2K	50	60	65	70	75	80
	2L	70	80	90	95	105	115
	2M	70	80	90	95	105	115

In this design #1 is longer as it has one duct connection downstream. Having a trunk reduction now repressurizes the system and you start again. Supply run #2 has three runs downstream and the 2I fitting would have an equivalent length of 95'.

In this design #1 is longer as it has one duct connection downstream. Having a trunk reduction now repressurizes the system and you start again. Supply run #2 has three runs downstream and the 2I fitting would have an equivalent length of 95’.

EXAMPLE DUCT PLAN



Calculation for run #1. The trunk length is from the furnace to the top takeoff at 5’. The run out length is from the top takeoff to the supply boot. Then add the equivalent lengths for the fittings for a total of 310’. Is supply #1 the longest?

Effective Length Worksheet

Element	Supply Run ID Number				Element	Return Run ID Number			
	1					R1			
Trunk Length	5'				Trunk Length	30'			
Trunk Length					Trunk Length				
Trunk Length					Trunk Length				
Runout Length	30'				Runout Length				
Group 1	120'	120'	120'	120'	Group 5 2*45	90'			
Group 2	75'				Group 6	15'			
Group 3					Group 7				
Group 4	80'	80'	80'	80'	Group 8				
Group 8					Group 10				
Group 9					Group 11				
Group 11					Group 12				
Group 12					Group 13				
Group 13					Other				
Other					Other				
Total Length	310'				Total Length	135 '			

12Q

EL Values	A1/A2	A1/A2
Slope	2	4
1:1	10	10
2:1	5	5
4:1	5	5

FROM MANUAL D

Effective Length Worksheet

Element	Supply Run ID Number				Element	Return Run ID Number			
	1	2	4			R1			
Trunk Length	5'	16'	26'		Trunk Length	30'			
Trunk Length					Trunk Length				
Trunk Length					Trunk Length				
Runout Length	30'	15'	25'		Runout Length				
Group 1	120'	120'	120'	120'	Group 5 2*45	90'			
Group 2	75'	95'	65'		Group 6	15'			
Group 3					Group 7				
Group 4	80'	80'	80'	80'	Group 8				
Group 8					Group 10				
Group 9					Group 11				
Group 11					Group 12				
Group 12		10'	10'		Group 13				
Group 13					Other				
Other					Other				
Total Length	310'	336'	326'		Total Length	135 '			

Looks like supply #2 is the longest. Now we can finish the friction rate calculation.

Xcel Energy

Manual D for Designers

Friction Rate Worksheet

Step 1) Manufacturer's Blower Data

External static pressure (ESP) = 0.7 IWC   Cfm = 600

Step 2) Component Pressure Losses (CPL)

Direct expansion refrigerant coil	0.25
Electric resistance heating coil	
Hot water coil	
Heat exchanger	
Low efficiency filter	
High or mid-efficiency filter	0.1
Electronic filter	
Humidifier	
Supply outlet	0.03
Return grille	0.03
Balancing damper	0.03
UV lights or other component	
Total component losses (CPL)	0.44 IWC

Step 3) Available Static Pressure (ASP)

ASP = (ESP - CPL) = (0.7 - 0.44) = 0.26 IWC

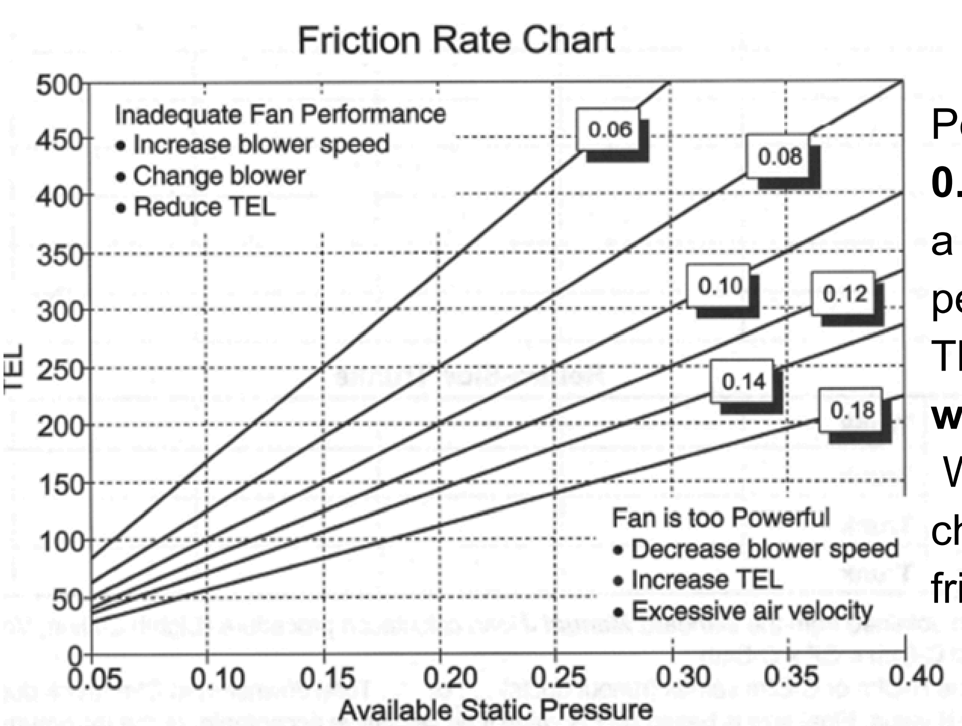
Step 4) Total Effective Length (TEL)

Supply-side TEL + Return-side TEL = (336 + 135) = 471 Feet

0.26 * 100/471 = 0.05

Step 5) Friction Rate Design Value (FR)

FR value from friction rate chart = 0.05 IWC/100

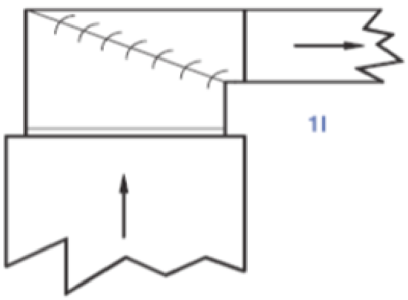


Per Manual D the friction below **0.06** and above **0.18** will result in a duct system that will not perform properly.

The example design **will not work**.

What one fitting could be changed and result in a correct friction rate?

If we were to change the furnace fitting from the 1H to a 1I that would reduce the total equivalents length by 100’. We realize that turning vanes is not something you typically see in homes…but they do exist.

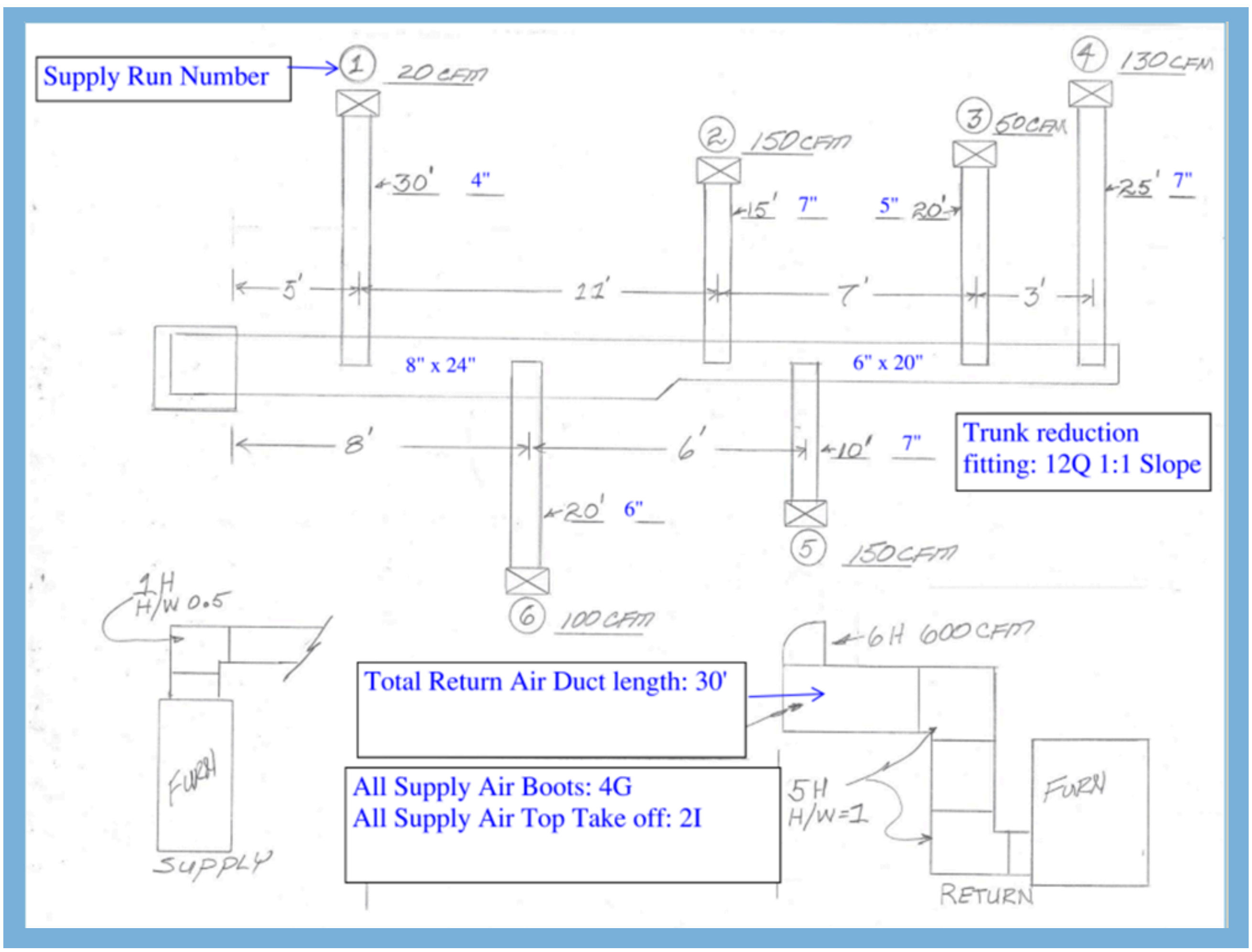


With Vanes 1I	EL = 20

FROM MANUAL D

Now the friction rate math is: 0.26 * 100/371 = 0.07 Passes!!

With the friction rate now known for that system we can use the ACCA DuctWheel to size the ductwork. App Available at: https://apps.apple.com/us/app/acca-ductwheel/id424430207



Example for required cfm for each room

The required cfm to each room is relative to the rooms calculated load. Essentially if the room requires 5% of the equipment's capacity the room will need 5% of the blower cfm.

To determine the required cfm per room you must calculate the heating and cooling factors.
(Wrightsoft labels this as 'Air Flow Factor')

- Heating Factor = Blower Cfm / MJ8 Heat Loss (for structure)
- Cooling Factor = Blower Cfm / MJ8 Sensible Load (for structure)
-

Solve for today's house
Heating Factor = 830 / 26,853 = .031* the rooms heat loss = required cfm
Cooling Factor = 995 / 14,954 = .067 * the rooms heat gain = required cfm

Design Information

Weather: Denver, CO, US

Winter Design Conditions

Outside db	-3	°F
Inside db	70	°F
Design TD	73	°F

Summer Design Conditions

Outside db	90	°F
Inside db	75	°F
Design TD	15	°F
Daily range	H	
Relative humidity	50	%
Moisture difference	-36	gr/lb

Heating Summary

Structure	26853	Btuh
Ducts	0	Btuh
Central vent (64 cfm)	4213	Btuh
Humidification	0	Btuh
Piping	0	Btuh
Equipment load	31066	Btuh

Sensible Cooling Equipment Load Sizing

Structure	14954	Btuh
Ducts	0	Btuh
Central vent (64 cfm)	877	Btuh
Blower	0	Btuh
Use manufacturer's data	y	
Rate/swing multiplier	1.00	
Equipment sensible load	15832	Btuh

Infiltration

Method	Simplified	
Construction quality	Average	
Fireplaces	0	

	Heating	Cooling
Area (ft²)	3600	3600
Volume (ft³)	14464	14464
Air changes/hour	0.28	0.15
Equiv. AVF (cfm)	67	36

Latent Cooling Equipment Load Sizing

Structure	274	Btuh
Ducts	0	Btuh
Central vent (64 cfm)	-1281	Btuh
Equipment latent load	0	Btuh
Equipment total load	15832	Btuh
Req. total capacity at 0.85 SHR	1.6	ton

Heating Equipment Summary

Make	Carrier	
Trade	Carrier	
Model	58MCB040-12x	
AHRI ref no.	144278	
Efficiency	92.1	AFUE
Heating input	40000	Btuh
Heating output	33156	Btuh
Temperature rise	44	°F
Actual air flow	830	cfm
Air flow factor	0.031	cfm/Btuh
Static pressure	0.70	in H2O
Space thermostat		

Cooling Equipment Summary

Make	Carrier	
Trade	BASE 13 PURON AC	
Cond	24ABB324(A,W)31	
Coil	CAP**2414A**++TDR	
AHRI ref no.	3250356	
Efficiency	11.0 EER, 13 SEER	
Sensible cooling	18835	Btuh
Latent cooling	2765	Btuh
Total cooling	21600	Btuh
Actual air flow	995	cfm
Air flow factor	0.067	cfm/Btuh
Static pressure	0.70	in H2O
Load sensible heat ratio	1.00	