

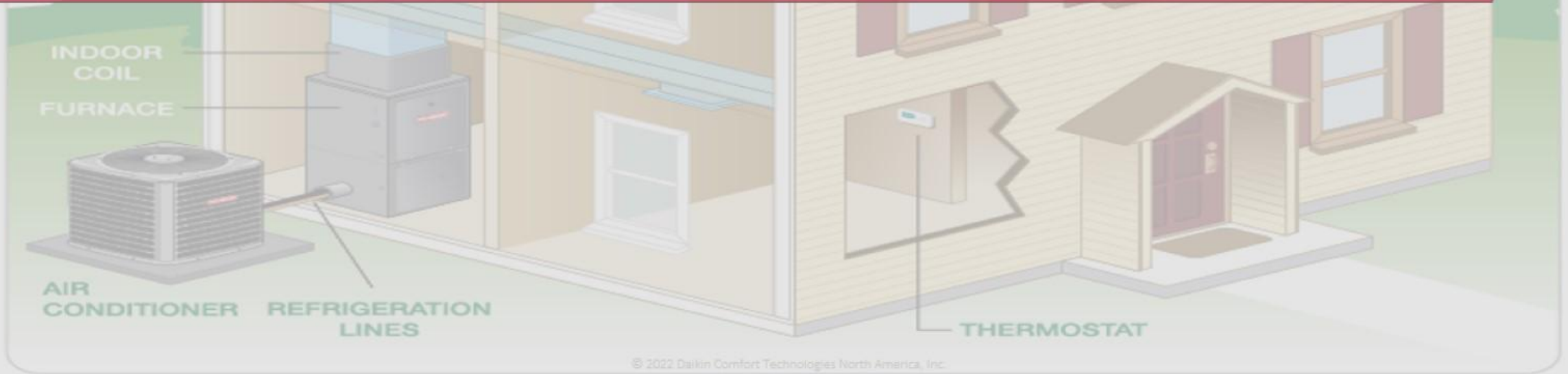


Air Conditioning & Heating



# Air Distribution and Troubleshooting

1006-0005 Technical Training Module TRM-1



OnlyFans

You know, airflow and stuff

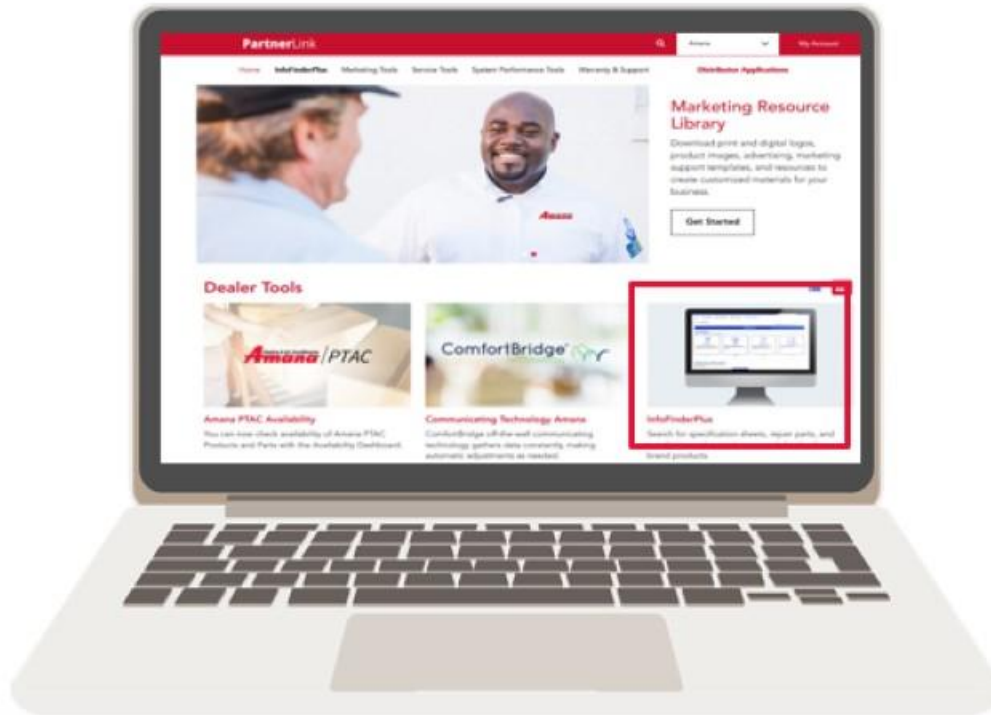
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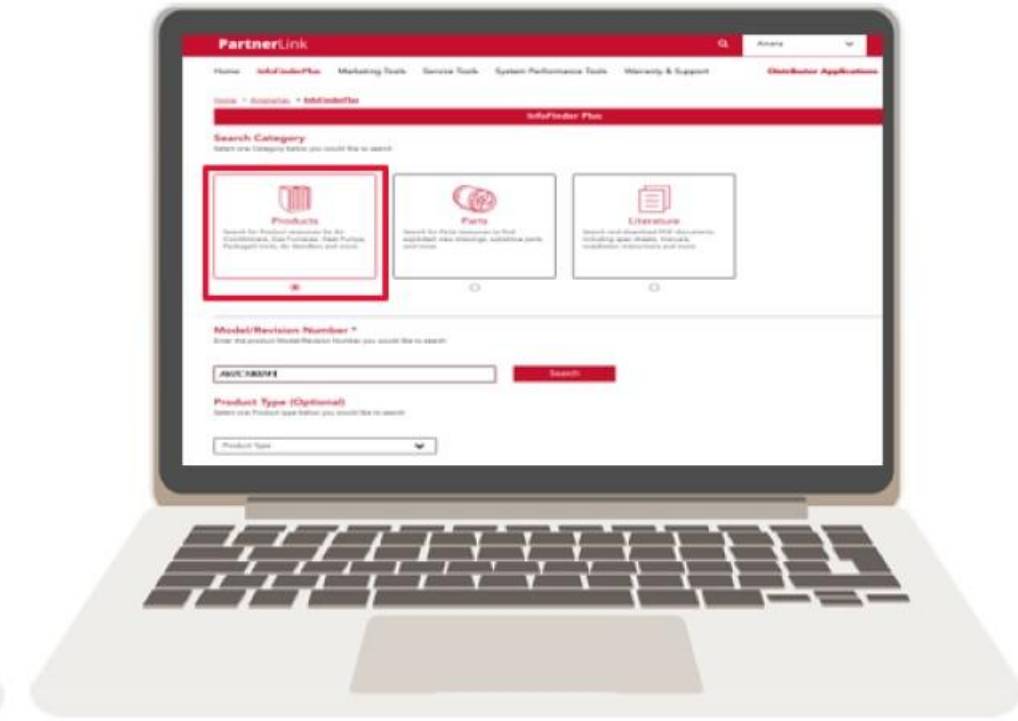


# Resources

- **PartnerLink** resource for equipment manuals, information, and guides
- <https://partnerlinkmarketing.goodmanmfg.com/>
- Login with credentials
- Select option for “InfoFinderPlus” then “Products”



<https://www.amana-hac.com/terms-of-use>



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# Resources

## ■ Daikin Tech Hub App

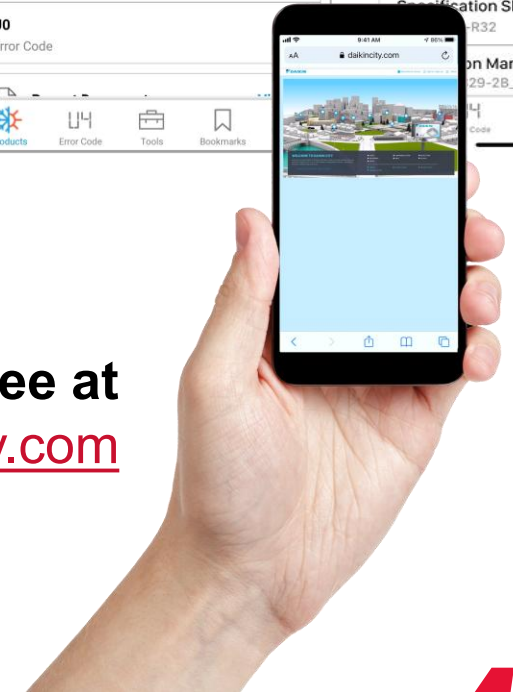
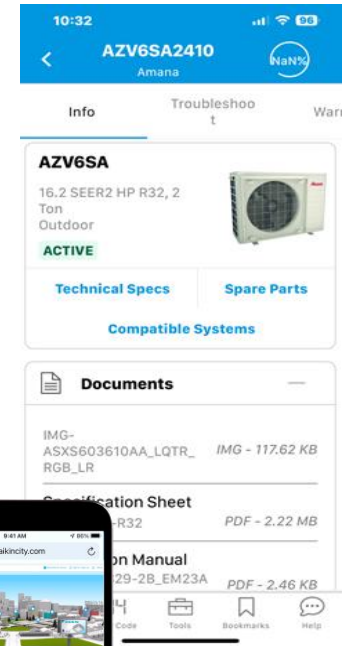
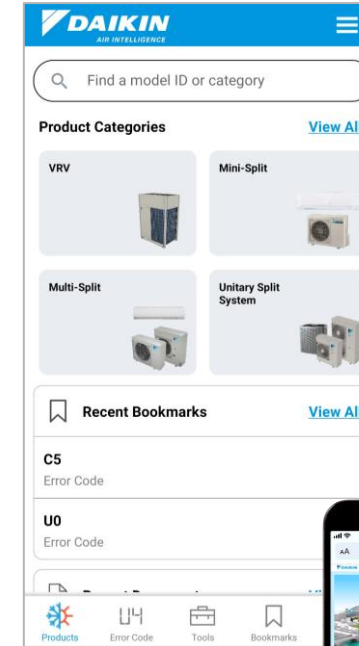
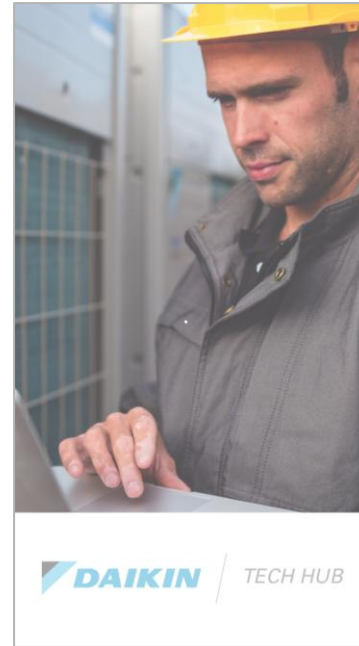


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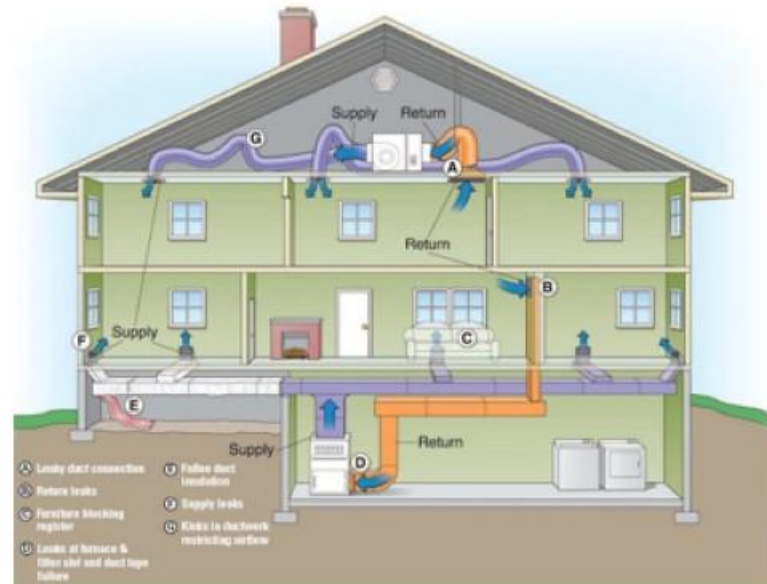


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# Module 1



# Common Airflow Issues

## Learning Objectives

- Discuss the common issues that create airflow issues

# Common Airflow Issues

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As you view this program, keep one very important rule in mind:

**NO TEST IS VALID  
IF THE AIRFLOW IS NOT CORRECT!  
No Pressures!!  
No Temperatures!!  
No Current Draws!!**

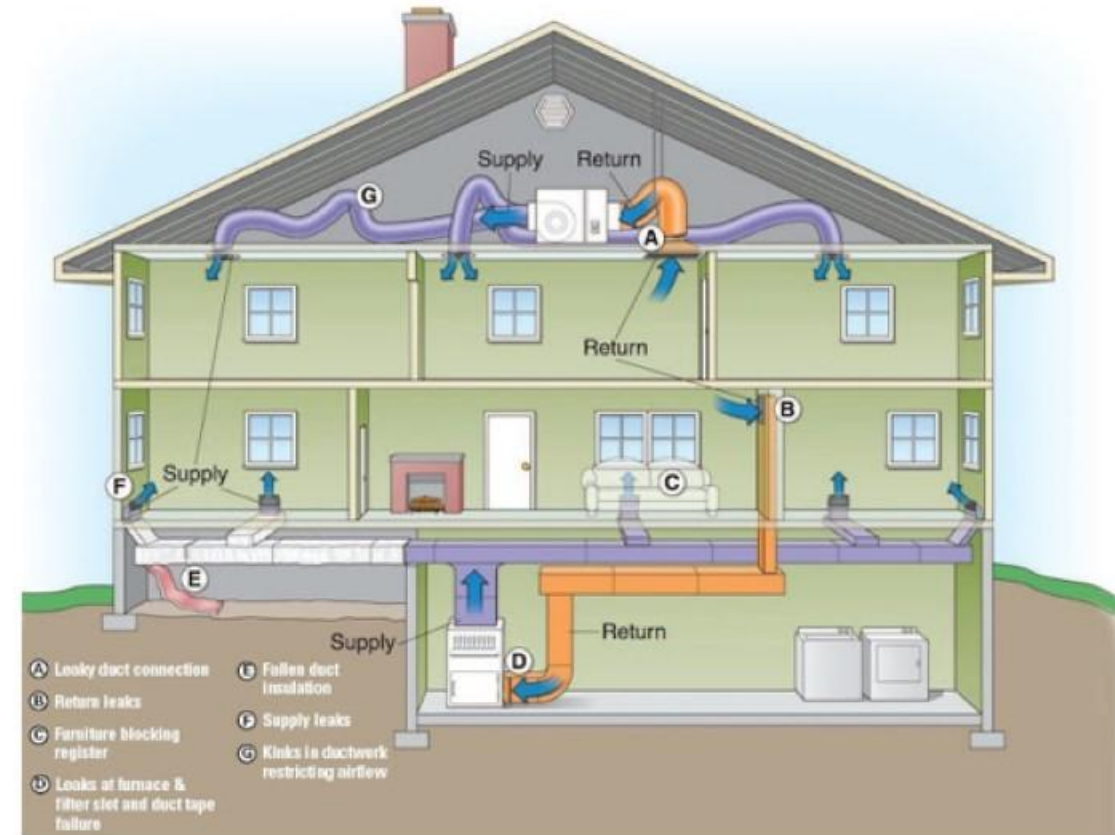
Before proceeding, make sure that all registers and grills are open, filters, blowers and coils are clean, and that blowers and fans are operating properly.

*"A buildup of .042(1/20) inches of dirt on the heating or cooling coil can result in a decrease in efficiency of 21%."* -**Environmental Protection Agency**

*"1/8th of an inch of dirt and dust build-up on the blower wheel can reduce airflow by up to 30%"* -**Texas A&M Study**

# Common Airflow Issues

- Incorrect Blower Speed
- Clogged Evaporator Coil
- Disconnected and Crushed Air Ducts
- Dirty Fan Blower
- Distance from the Furnace, Air Conditioner or Heat Pump
- Improperly Sized Heating and Cooling Equipment
- Lack of Return Air
- Leaky Air Ducts
- Pressure Imbalance



# Common Airflow Issues

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## Low Airflow (Cooling) can cause:

- Low superheat & suction pressure
- Evaporator coil freeze-ups
- Compressor running oil pump out
- Reduced equipment life
- Poor capacity
- Sweating of registers, grills and even duct

## Low Airflow (Heating) can cause:

- High temperature rise
- Space temperature fluctuations
- Limit switch tripping
- Heat exchanger failure
- Heat strip failures
- High pressure switch tripping
- Increased utility costs

# Common Airflow Issues

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High Airflow (Cooling) can cause:

- High superheat & suction pressure
- Poor humidity control
- Compressor thermal overload tripping
- Reduced equipment life
- Poor capacity
- Higher utility costs
- Reduced comfort levels
- Increased noise levels

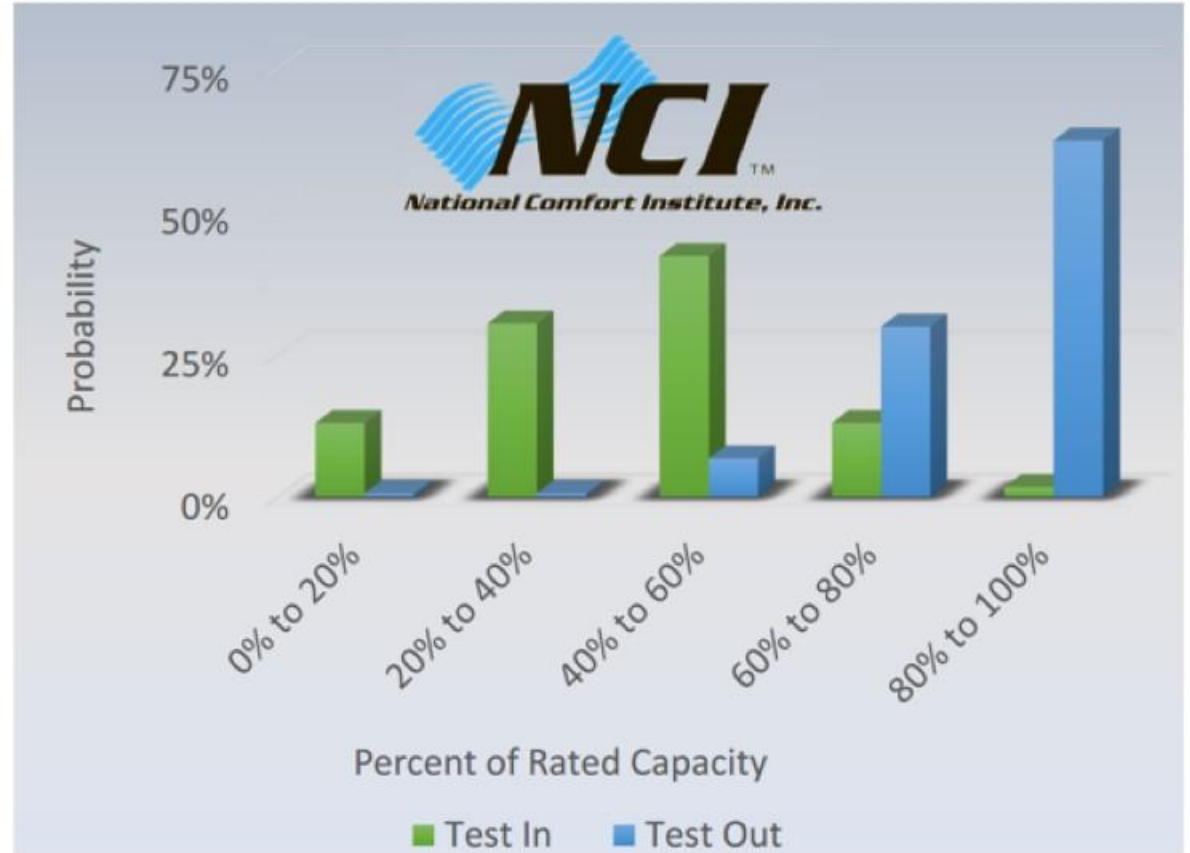
High Airflow (Heating) can cause:

- Low temperature rise
- Heat exchanger failure
- Poor venting
- Increased utility costs
- Increased noise levels

# Common Airflow Issues

## NCI System Performance Score Data

- 85% of systems Test In at less than 60%
- After renovations, 75% of systems Test Out at better than 75%



## Module 2



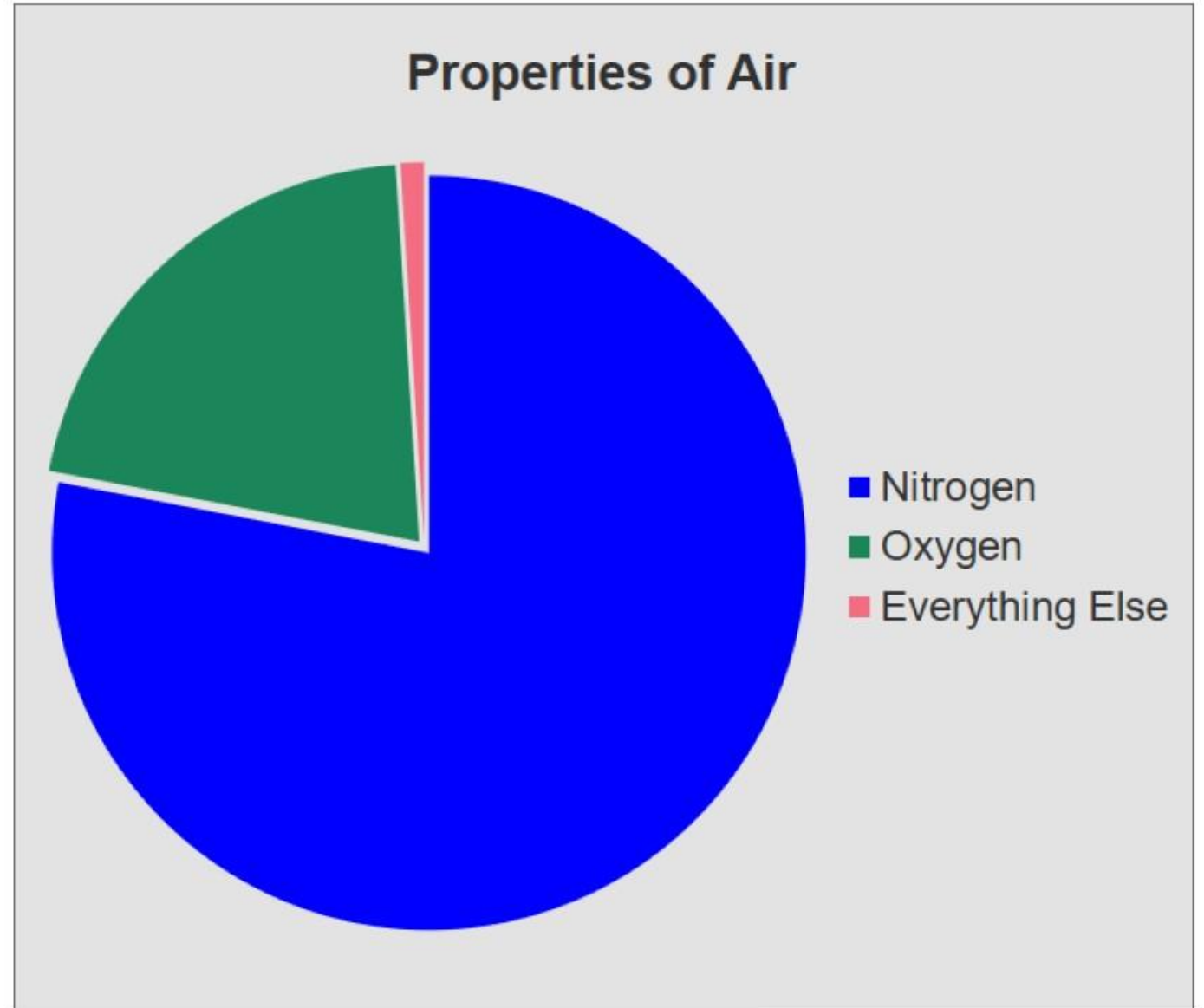
# Properties of Air

## Learning Objectives

- Discuss the properties of Air
- Understanding the Psychrometric Chart

# Properties of Air

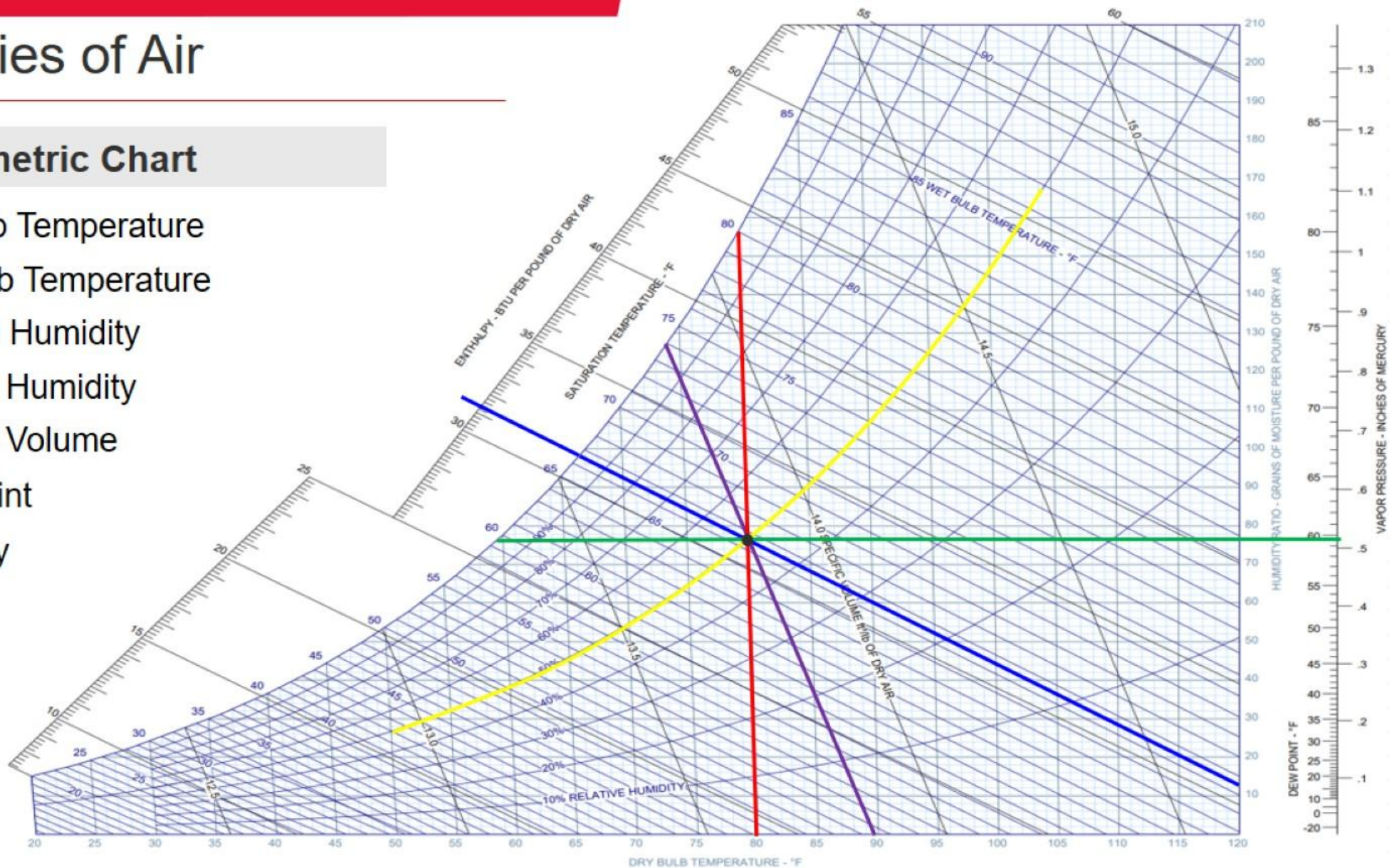
- Air consists mainly of about 78% Nitrogen and about 21% Oxygen.
- Trace gasses account for less than 1% of air and have negligible effect on our calculations



# Properties of Air

## Psychrometric Chart

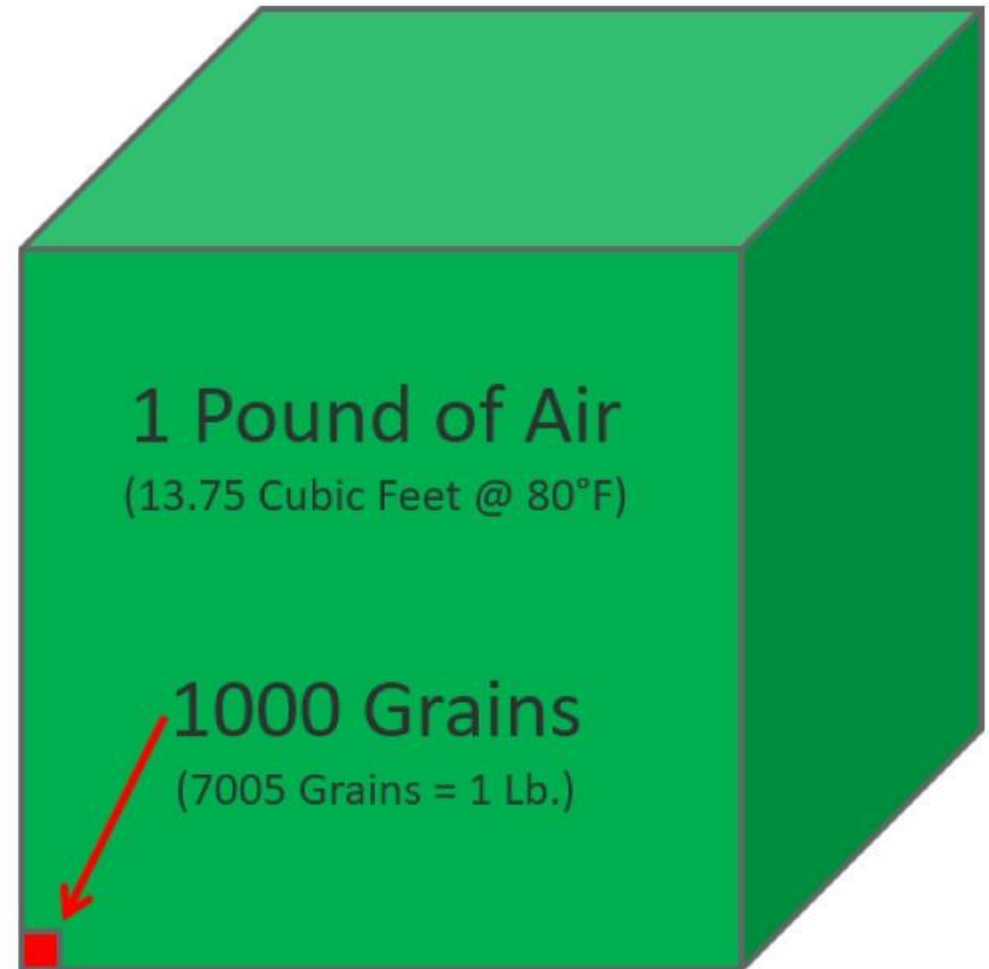
- Dry Bulb Temperature
- Wet Bulb Temperature
- Relative Humidity
- Specific Humidity
- Specific Volume
- Dew Point
- Enthalpy



# Properties of Air

## Humidity

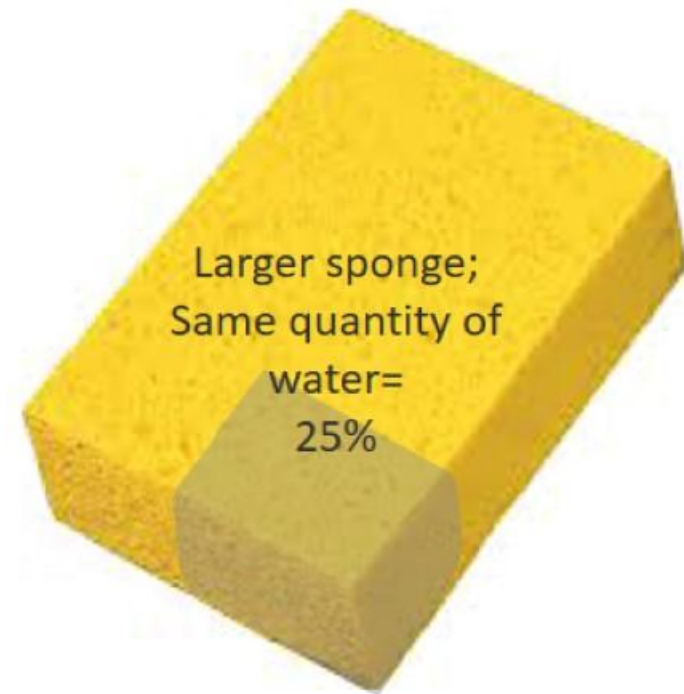
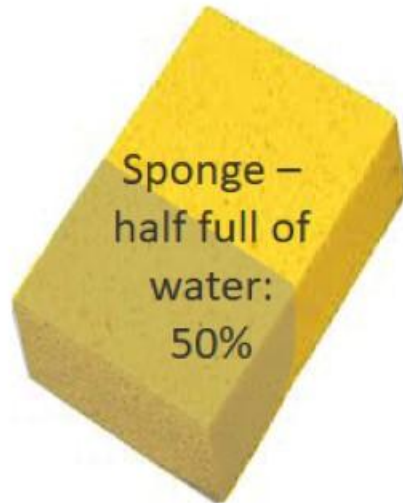
- Humidity is a reference to the amount of water (in the form of vapor) that is contained in the air, usually expressed in grains.
- The amount of moisture is very small-- there are approximately 7005 grains to one pound of water.
- Humidity (the LATENT Load) accounts for nearly one third of the average air conditioner's load capacity.



# Properties of Air

## Volume of Air

- As air is heated, it expands.
- The same amount of moisture now represents a smaller percentage of what the air can hold.



# Properties of Air

## Weight of Air

**Would You believe that the air in your house, that your HVAC system moves each day, likely weighs more than the house?**

- Standard air weighs about 0.075 lb. per cubic foot
- 2 ½ ton AC moving 1000 CFM
- $0.075 \times 60 = 4.5$  (converts CFM to lb. per hour)
- $1000 \times 4.5 = 4500$  lb. per hour
- 20 hour run time (August) = **90,000 lb.!!**
- **45 TONS in one day...**
- **That is more than the house weighs\*!!**

\* The average frame house, minus slab or foundation, weighs approximately 55 lbs. per square foot

# Properties of Air

## Psychrometers

- Psychrometers come in many styles from the “sling psychrometer” to digital models that do not require movement through the air.
  - A psychrometer measures humidity by taking both a wet-bulb and a dry-bulb temperature reading.
  - With those two values known, the other properties of the air, including its moisture content, can be determined by computation or by reading a psychrometric chart.



## Module 3



# Static Pressure

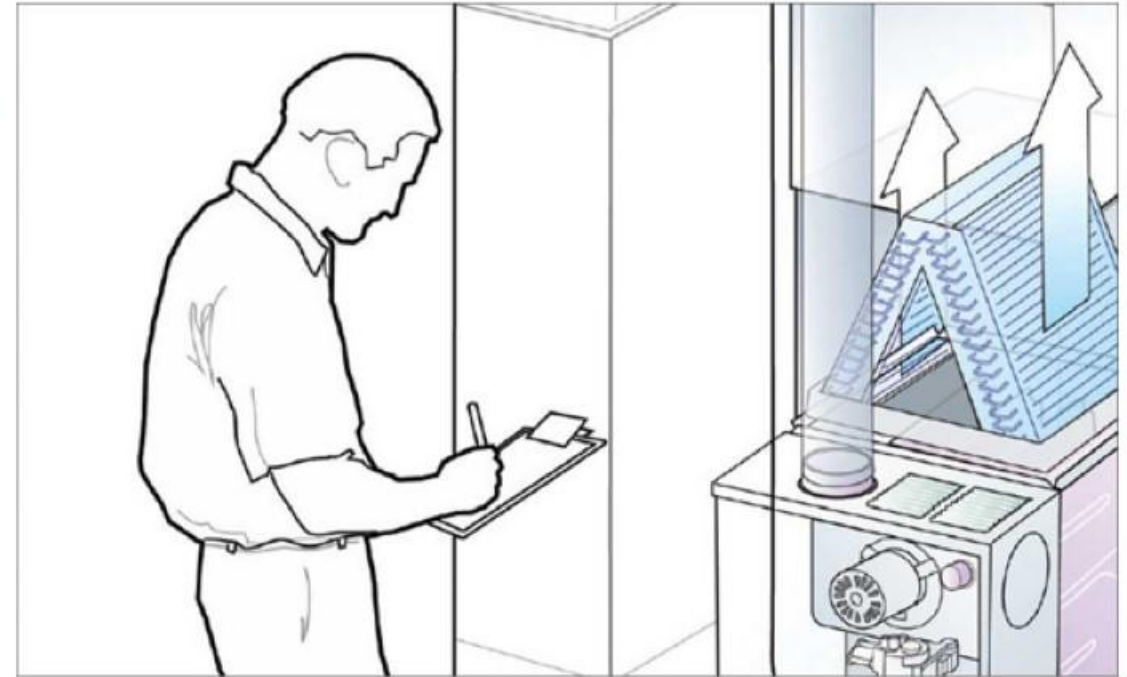
## Learning Objectives

- Discuss the tools and methods for checking static pressure

# Static Pressure

Static pressure is used to evaluate the amount of impact various ventilation system components have on the airflow path within a given system.

- A mechanical ventilation system operates with the static pressure in balance.
  - The fans create velocity pressure to move air through the system.
  - All other components create static pressure which causes resistance to air moving through the system.
  - The velocity pressure created by the fans equals the static pressure created by the system.
- Static & velocity pressures are usually measured in inches of water column.
  - 1 pound per square inch = 27.7076 inches of water



“ThE oLd OnE wOrKeD FiNe!”

Different types of blower motors

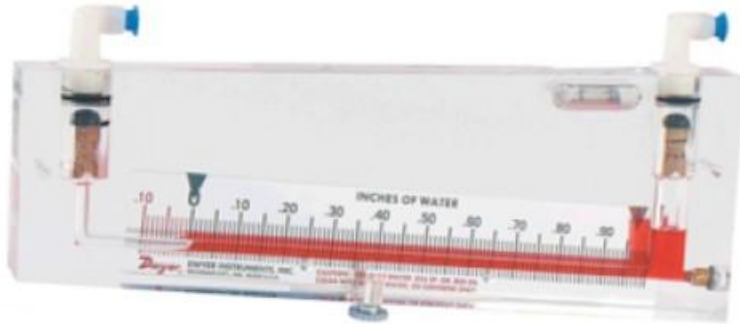
- PSC (Permanent Split Capacitor)
- Constant Torque (X13)
- Constant Volume (Variable Speed)

# Static Pressure

## Measuring Devices

Static Pressure in a system is can be measure by any of the many measuring devices on the market today.

- Magnehelic™
- Digital Manometer
- Incline Manometer



# Static Pressure

## Total External Static Pressure

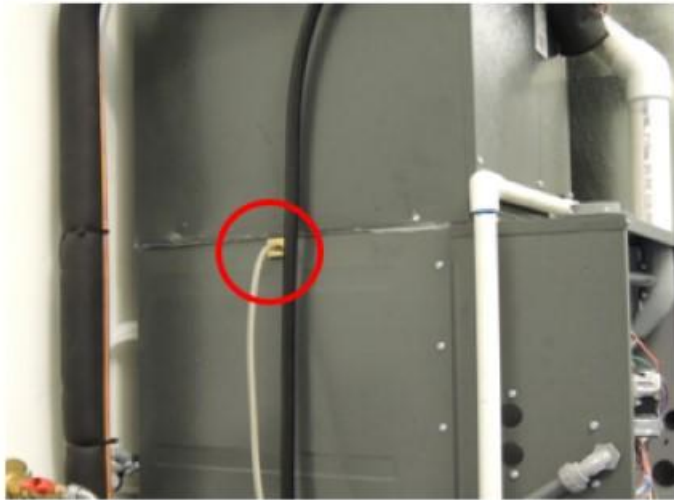
- Checking Total External Static Pressure (TESP) is a great way to gauge the health of an HVAC system.
- Checking TESP is also required on most models to properly set the speed of the indoor blower.
  - TESP can indicate if sufficient air volume is passing through the air handler, furnace or package unit.
  - This test cannot verify where the air is going, only that the volume through the unit is correct.
- Before testing TESP:
  - Make sure that all duct dampers and registers are open and un-blocked.
  - Ensure that a CLEAN filter is in place.
  - Make sure that all interior doors are open.

Most residential systems, including  
Goodman/Amana,  
are designed to operate  
at **0.5" water column**  
**maximum**  
Total External Static Pressure.

# Static Pressure

## Measuring TESP

- Total External Static Pressure is a combination of two readings:
  - One taken at the inlet of the unit.
  - And the other at the outlet of the unit.
- Readings can be taken simultaneously or added together to determine the Total Static Pressure.



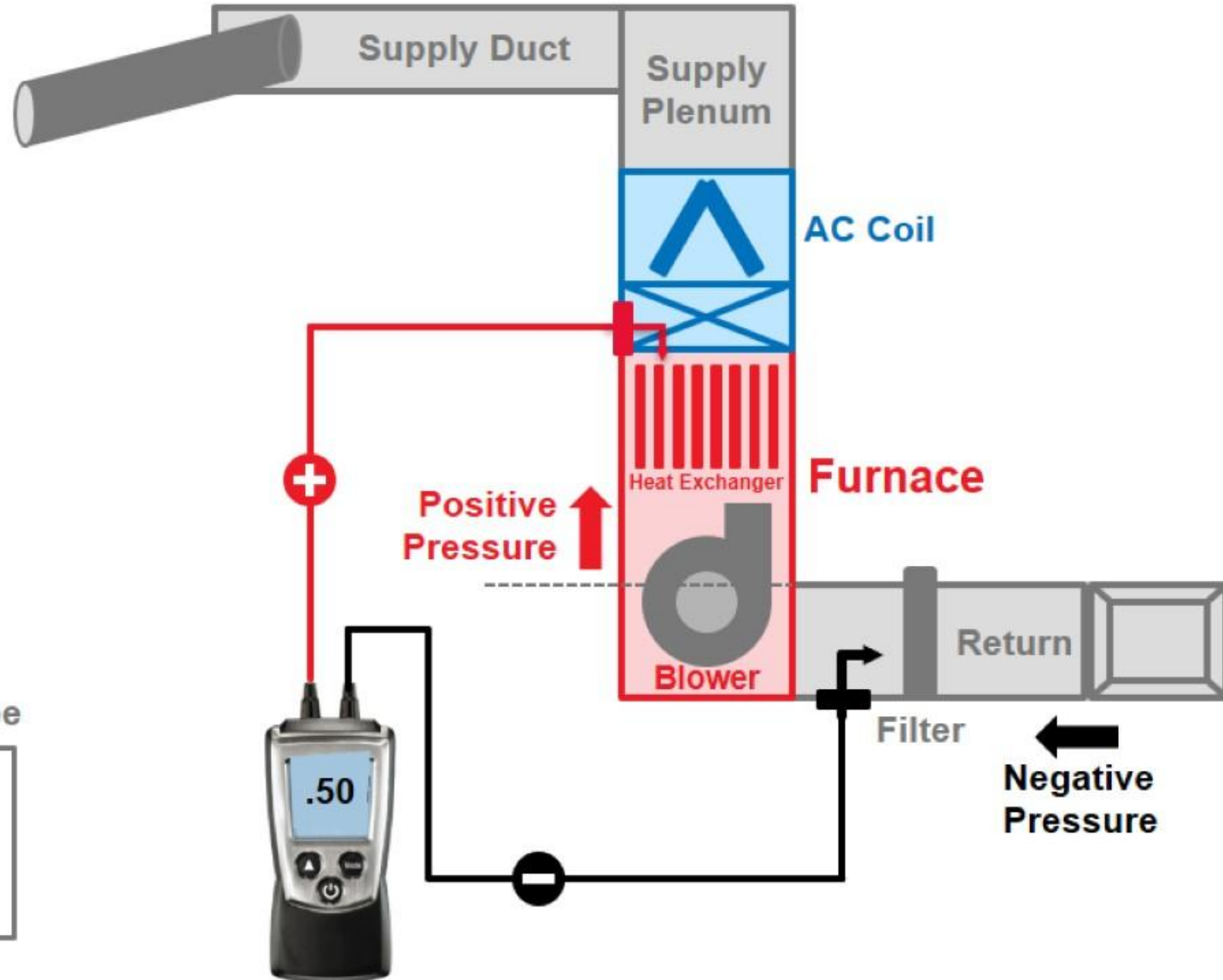
Static Pressure tap at outlet



Static Pressure tap at inlet

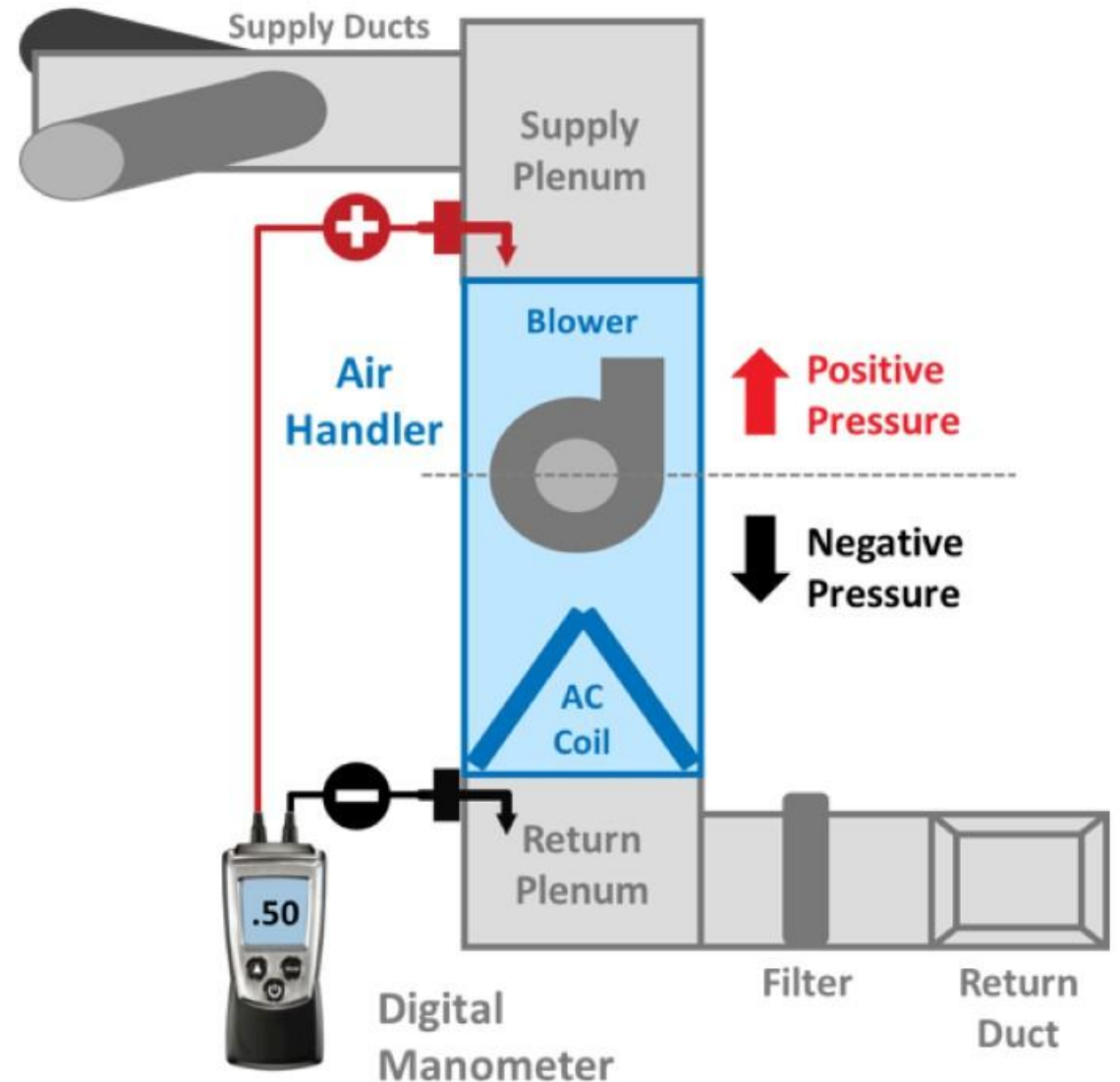
# Static Pressure | Gas Furnace and AC Coil

- The design static of most furnaces is 0.5 inches water column.
- Use a manometer to measure the static pressure of the furnace only.
  - Supply side is measured between the heat exchanger and evaporator coil.
  - Return side is measured between the blower wheel and filter.
- The combination of both the supply and return equal TESP.



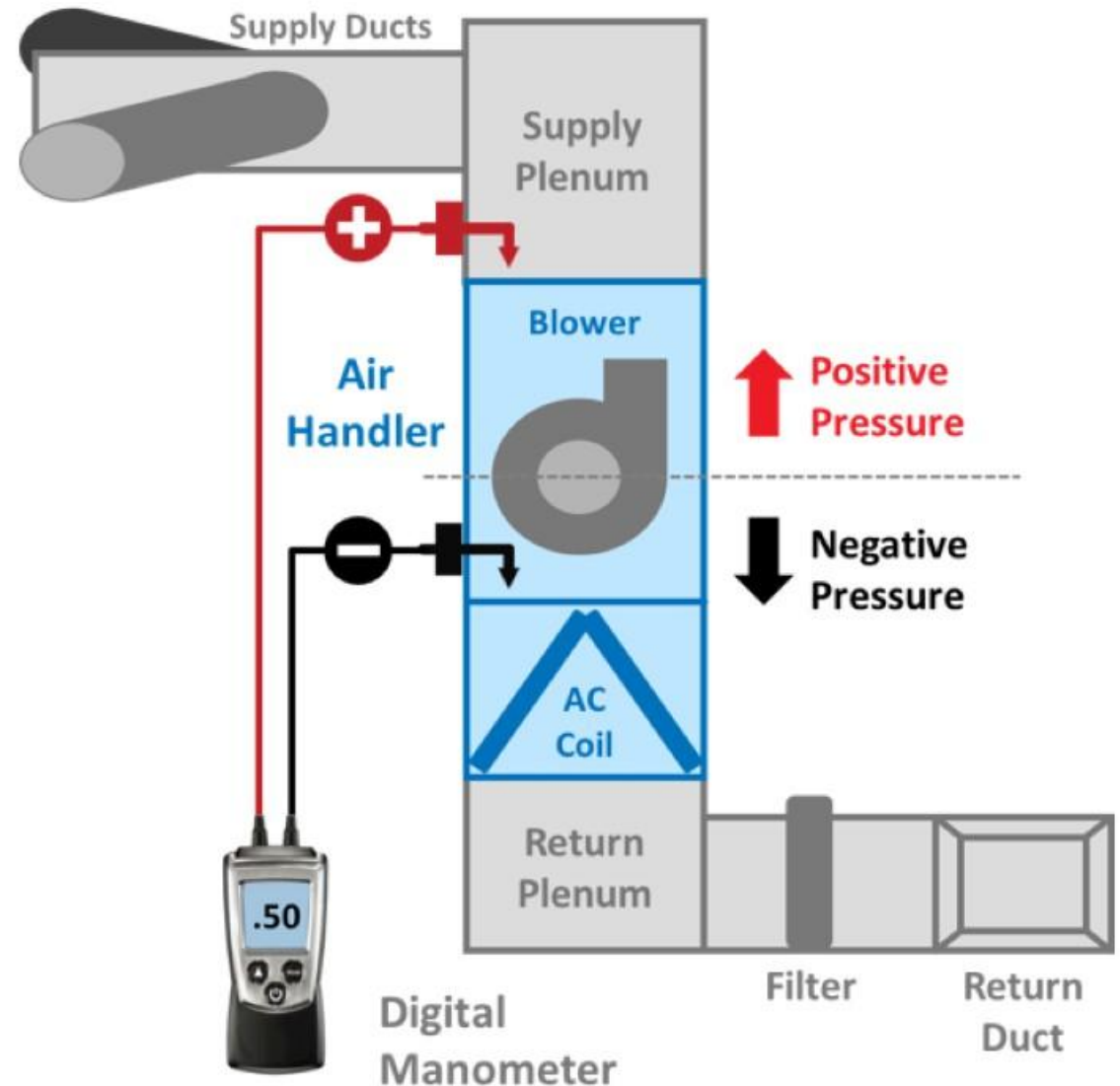
# Static Pressure | Single Piece Air Handler

- On a single piece air handler, the evaporator coil has been installed at the factory and is already considered in static pressure calculation.
- Use a manometer to measure the static pressure of the air handler only.
  - Measure static pressure of the supply duct at the outlet of the air handler.
  - Measure the static pressure of the return duct at the inlet of the air handler.
- **Note:** Both readings may be taken simultaneously and read if so desired.



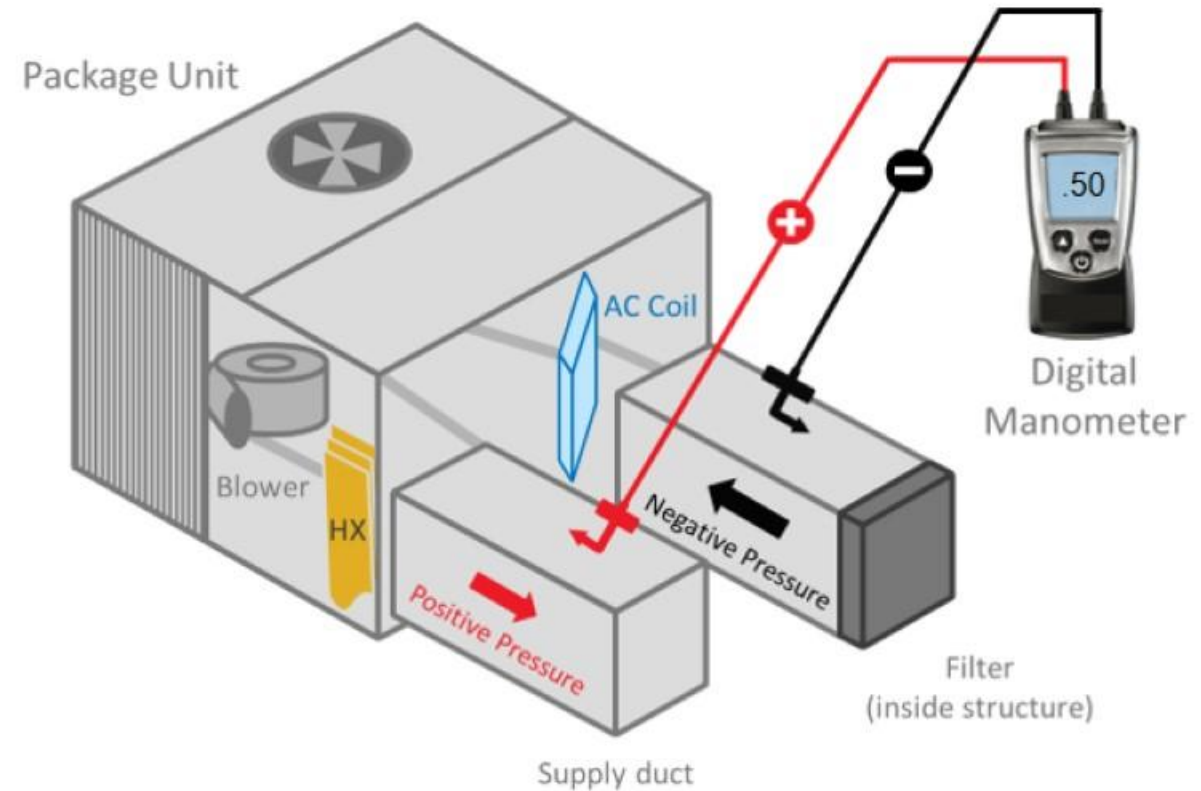
# Static Pressure | Two Piece Air Handler

- On a two-piece air handler, the evaporator coil is not part of the air handler so it must be not considered in calculating the static pressure.
- Use a manometer to measure the static pressure of the air handler's blower assembly only.
  - Measure the static pressure of the supply duct at the outlet of the unit.
  - Measure the static pressure between the outlet of the evaporator coil and the inlet of the air handler.
- **Note:** Both readings may be taken simultaneously if so desired.



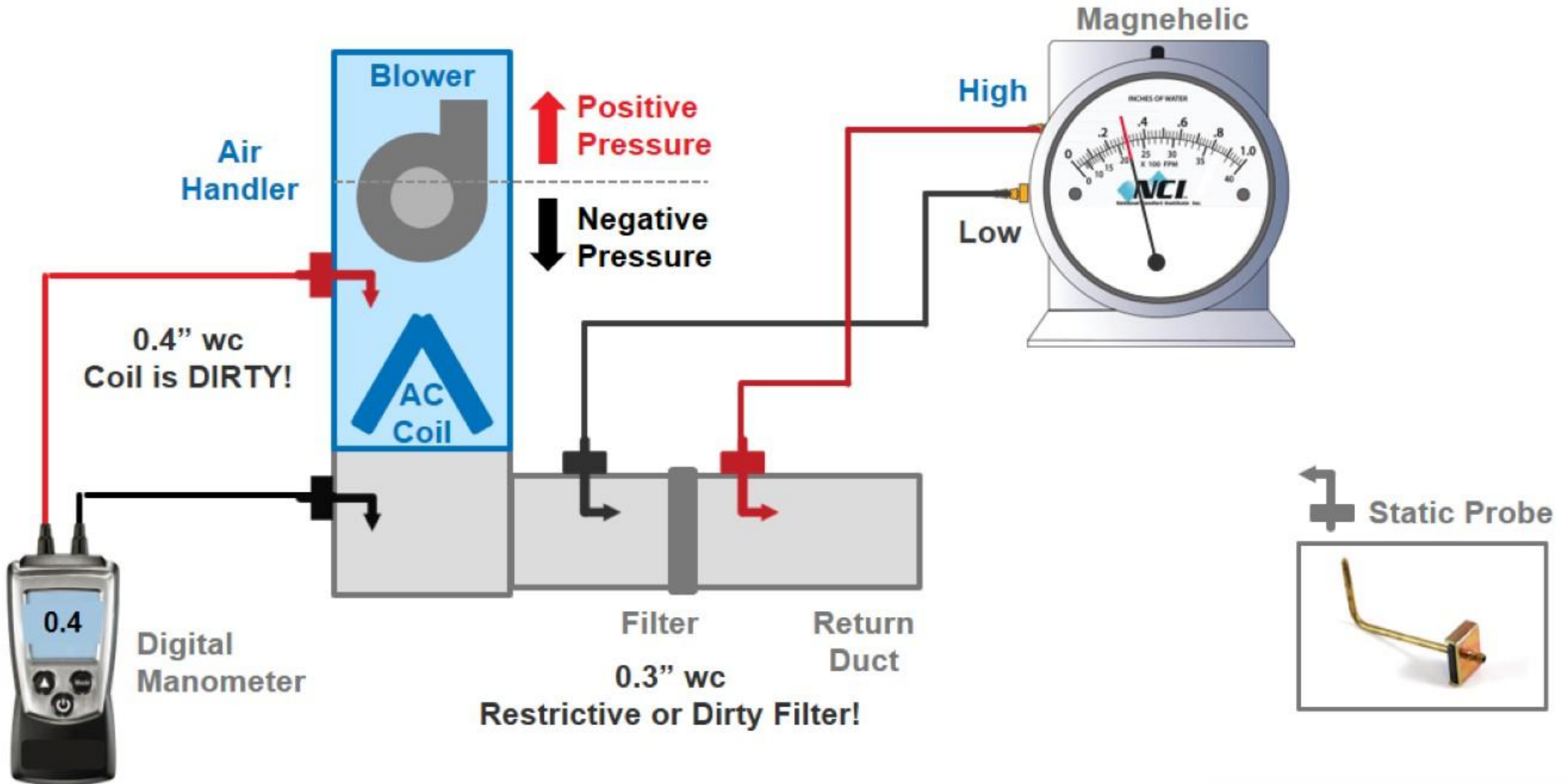
# Static Pressure | Residential Package Unit

- On residential package units, all factory installed internal components are considered in the calculation.
- Checking static pressure should be done in a “working scenario”, which means all doors are on, filters in-place, and dampers set to their normal operating position.
- Use a manometer to measure the static pressure at both the supply and return ducts.
  - Measure the static pressure of the supply duct at the outlet of the unit.
  - Measure the static pressure of the return duct at the inlet of the unit.
- **Note:** Both readings may be taken simultaneously if so desired.



# Static Pressure

## Testing for Pressure Drop | Individual Components



# Static Pressure

## Checking Cooling Airflow

- Determine which blower speed is operating in cooling.
- Measure the Total External Static Pressure
- Reference unit's blower performance tables to determine the volume of air moving through the unit.

MODEL	THERMOSTAT CALL	TAP #	EXTERNAL STATIC PRESSURE, (INCHES WATER COLUMN)							
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
			CFM	CFM	CFM	CFM	CFM	CFM	CFM	CFM
<b>*M9S960403A*</b>	Y2	F01	705	661	617	564	509	455	405	362
		F02	1079	1055	1027	994	965	935	906	863
		F03	915	881	846	814	780	737	695	652
		F04	887	855	823	790	751	705	666	608
		F05 <sup>^</sup>	1135	1106	1078	1049	1021	994	965	933
		F06	1189	1163	1138	1111	1085	1059	1032	1001
		F07	1266	1243	1218	1197	1172	1148	1123	1099
		F08	1313	1288	1261	1239	1215	1189	1165	1143
		F09	1342	1324	1305	1280	1263	1239	1216	1193

^ Default Speed

High Stage Cooling Airflow – \*M9S96

# Static Pressure

## Checking Heating Airflow

- Determine which blower speed is operating in heating.
- Measure the Total External Static Pressure
- Reference unit's blower performance tables to determine the volume of air moving through the unit and the approximate temperature rise when the furnace is firing at 100%.

MODEL	THERMOSTAT CALL	TAP #	EXTERNAL STATIC PRESSURE, (INCHES WATER COLUMN)												
			0.1		0.2		0.3		0.4		0.5		0.6	0.7	0.8
			CFM	RISE	CFM	RISE	CFM	RISE	CFM	RISE	CFM	RISE	CFM	CFM	CFM
*M9S960403A*	W/W1	F01^^	705	50	661	54	617	N/A	564	N/A	509	N/A	455	405	362
		F02^	1079	33	1055	34	1027	35	994	36	965	37	935	906	863
		F03	915	39	881	40	846	42	814	44	780	46	737	695	652
		F04	887	40	855	42	823	43	790	45	751	47	705	666	608

^ Default Speed

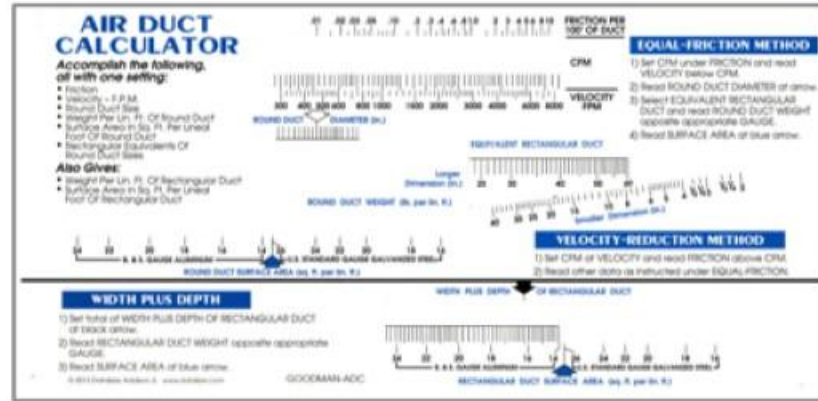
^^ Not Recommended For Heating

Heating Airflow – \*M9S96

TEMP RANGE

25-55

# Module 4



# Determining Airflow

## Learning Objectives

- Discuss the scope of determining airflow

## ***Sensible BTU Formula Definitions***

- ***Sensible BTU's*** – a unit of measurement of heat that causes a change in temperature
- ***Latent BTU's*** – a unit of measurement of heat that causes a change in state
- ***CFM*** – airflow in Cubic Feet Per Minute
- **$\Delta t$**  – a temperature difference. When measuring system BTU's, it is the difference between the return air temperature and the supply temperature
- ***1.08*** – constant equal to 60 min/hr x .075 lbs/cu ft (standard weight of air) x .024 BTU/lb (standard specific heat of air)

# Determining Airflow

## Airflow Formulas

- This airflow formula can be transposed to solve for different variables.
- If any two values are known, the third value can be determined.

$$\text{CFM} = \frac{\text{BTUH}_{(\text{SENSIBLE})}}{1.08 \times \Delta T}$$

$$\Delta T = \frac{\text{BTUH}_{(\text{SENSIBLE})}}{\text{CFM} \times 1.08}$$

$$\text{BTUH}_{(\text{SENSIBLE})} = \text{CFM} \times 1.08(\Delta T)$$

1.08 = Specific heat of air (0.24 BTU) x density (0.075 lb. per cubic foot) x 60 minutes

# Determining Airflow

## Calculating Gas Furnace Heating CFM Using Temperature Rise

If BTU output and operating temperature rise of a furnace is known, airflow through the unit can be calculated.

### ▪ Example

- Furnace Model \*M9S920603B\*
  - 60,000 BTU input x 92% efficiency = 55,200 BTU output
- Supply Temperature = 115°F
- Return Temperature = 70°F
- $\Delta T = 45^\circ\text{F}$

$$\text{CFM} = \frac{\text{BTUH (output)}}{1.08 \times \Delta T}$$

$$\text{CFM} = \frac{55,200}{1.08 \times 45}$$

$$\text{CFM} = \frac{55,200}{48.6}$$

$$\text{CFM} = 1,135$$

1.08 = Specific heat of air (0.24 BTU) x density (0.075 lb. per cubic foot) x 60 minutes

# Determining Airflow

## Calculating Heating CFM Required For Specific Temperature Rise

If BTU output of a furnace is known, CFM for a desired temperature rise can be calculated.

- Example

- Furnace Model \*M9S960603B\*
  - 60,000 BTU input x 96% efficiency = 57,660 BTU output
- Allowable temperature rise = 25°F - 55°F
  - Desired temperature rise 40°F (mid range)

$$\text{CFM} = \frac{\text{BTUH (output)}}{1.08 \times \Delta T}$$

$$\text{CFM} = \frac{57,600}{1.08 \times 40}$$

$$\text{CFM} = \frac{57,600}{43.2}$$

$$\text{CFM} = 1,333$$

1.08 = Specific heat of air (0.24 BTU) x density (0.075 lb. per cubic foot) x 60 minutes

# Determining Airflow

## Calculating Air Handler Heating BTUH Using Voltage And Amperage

If operating voltage and amperage of the air handlers' electric heaters is known, airflow through the unit can be calculated.

- Example

- Air Handler AMST24BU14\*\* with 10KW electric heater installed
  - Operating voltage of electric heaters = 238 Volts
  - Operating amperage of electric heaters = 21 Amps

$$\text{BTUH} = \text{Volts} \times \text{Amps} \times 3.412$$

$$\text{BTUH} = 238 \times 21 \times 3.412$$

$$\text{BTUH} = 4998 \times 3.412$$

$$\text{BTUH} = 17,053$$

Volts x Amps = Watts

1 Watt = 3.412 BTU

# Determining Airflow

## Calculating Air Handler Electric Heating CFM Using Temperature Rise

Once the BTU output of the electric heaters is known, measure the air handlers' temperature rise to calculate airflow through the unit.

### ▪ Example

- Air Handler AMST24BU14\*\* with 10KW electric heater installed
  - BTU output at 238 volts, 21 amps = 17,053
- Supply Temperature = 95°F
- Return Temperature = 70°F
- $\Delta T = 25^\circ\text{F}$

$$\text{CFM} = \frac{\text{BTUH (output)}}{1.08 \times \Delta T}$$

$$\text{CFM} = \frac{17,053}{1.08 \times 25}$$

$$\text{CFM} = \frac{17,053}{27}$$

$$\text{CFM} = 631$$

1.08 = Specific heat of air (0.24 BTU) x density (0.075 lb. per cubic foot) x 60 minutes

# Determining Airflow

## Air Duct Calculator

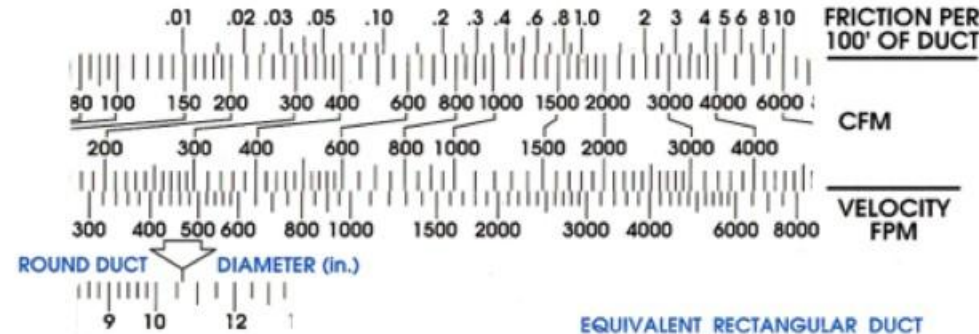
### AIR DUCT CALCULATOR

Accomplish the following, all with one setting:

- Friction
- Velocity - F.P.M.
- Round Duct Size
- Weight Per Lin. Ft. Of Round Duct
- Surface Area In Sq. Ft. Per Lineal Foot Of Round Duct
- Rectangular Equivalents Of Round Duct Sizes

Also Gives:

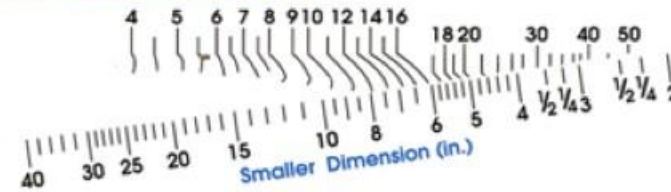
- Weight Per Lin. Ft. Of Rectangular Duct
- Surface Area In Sq. Ft. Per Lineal Foot Of Rectangular Duct



### EQUAL-FRICTION METHOD

- 1) Set CFM under FRICTION and read VELOCITY below CFM.
- 2) Read ROUND DUCT DIAMETER at arrow.
- 3) Select EQUIVALENT RECTANGULAR DUCT and read ROUND DUCT WEIGHT opposite appropriate GAUGE.
- 4) Read SURFACE AREA at blue arrow.

### EQUIVALENT RECTANGULAR DUCT

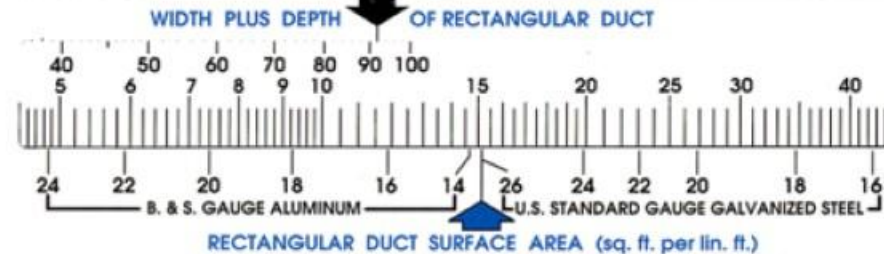


### VELOCITY-REDUCTION METHOD

- 1) Set CFM at VELOCITY and read FRICTION above CFM.
- 2) Read other data as instructed under EQUAL-FRICTION.

### WIDTH PLUS DEPTH

- 1) Set total of WIDTH PLUS DEPTH OF RECTANGULAR DUCT at black arrow.
- 2) Read RECTANGULAR DUCT WEIGHT opposite appropriate GAUGE.
- 3) Read SURFACE AREA at blue arrow.



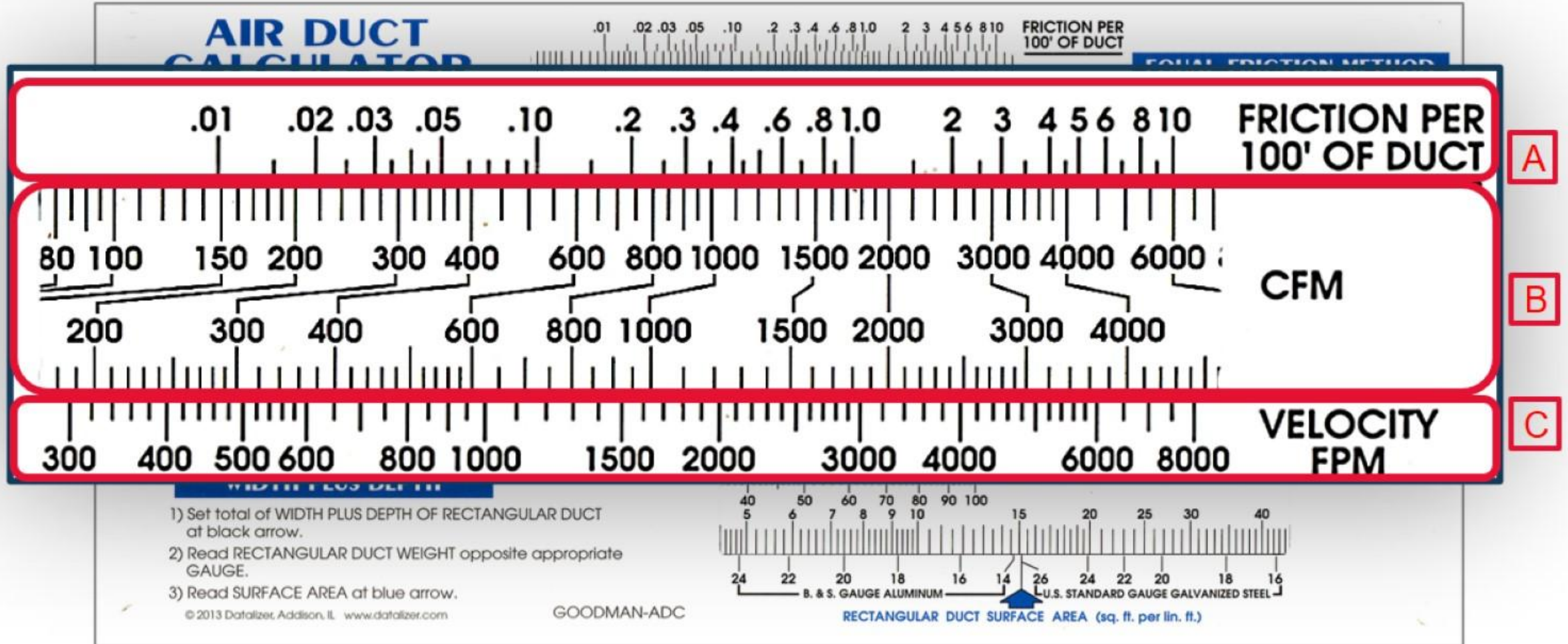
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GOODMAN-ADC

**For Sheet metal duct only!**

# Determining Airflow

## Air Duct Calculator



**For Sheet metal duct only!**

# Determining Airflow

## Air Duct Calculator | Round Duct

### AIR DUCT CALCULATOR

Accomplish all with one tool:

- Friction
- Velocity - FPM
- Round Duct Diameter
- Weight Per Foot
- Surface Area
- Foot Of Round Duct
- Rectangular Duct
- Round Duct

Also Gives:

- Weight Per Foot
- Surface Area
- Foot Of Round Duct

#### ACTION METHOD

FRICITION and read  
w CFM.  
DUCT DIAMETER at arrow.  
RECTANGULAR  
ROUND DUCT WEIGHT  
APPROPRIATE GAUGE.  
AREA at blue arrow.

### WIDTH PLUS DEPTH

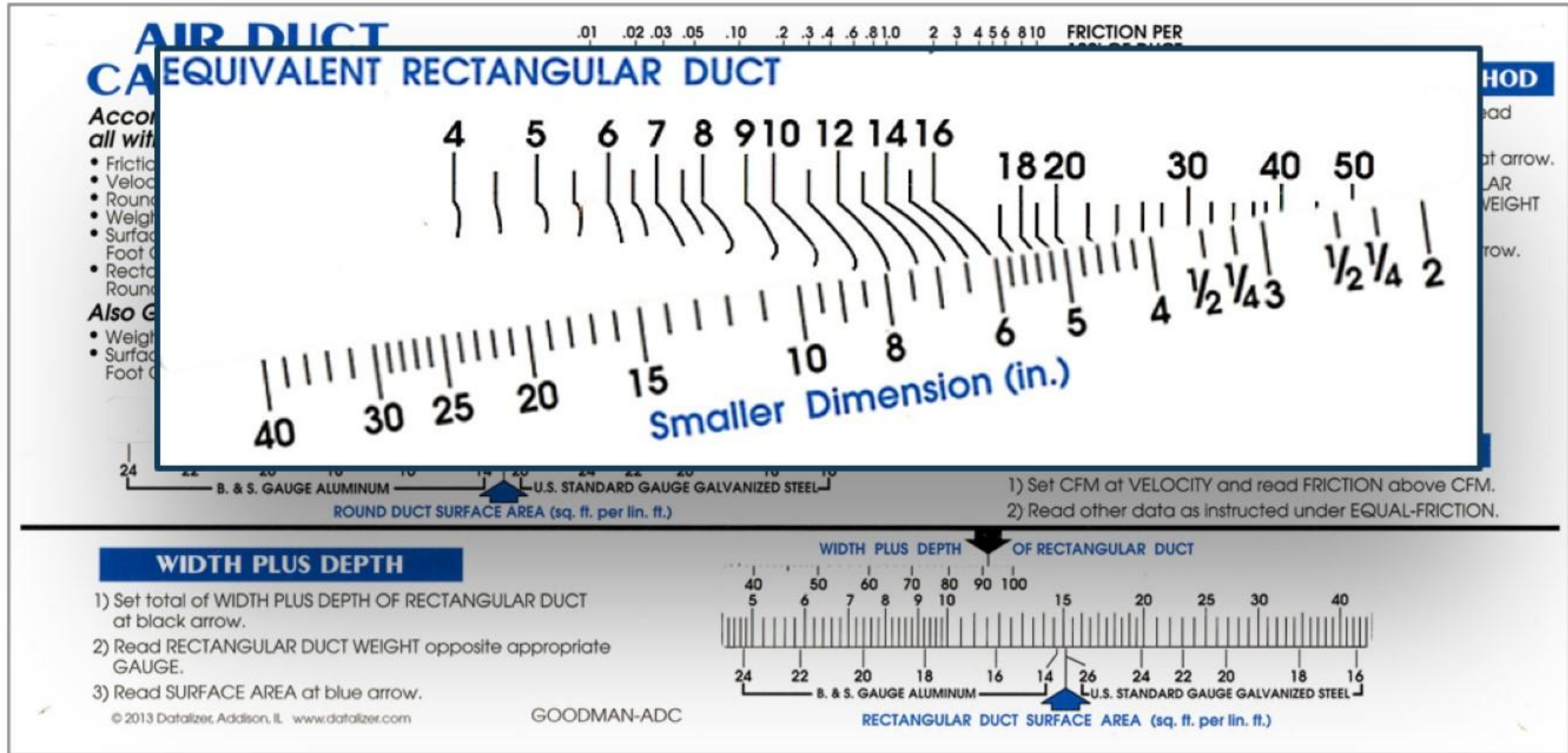
- 1) Set total of WIDTH PLUS DEPTH OF RECTANGULAR DUCT at black arrow.
- 2) Read RECTANGULAR DUCT WEIGHT opposite appropriate GAUGE.
- 3) Read SURFACE AREA at blue arrow.

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GOODMAN-ADC

# Determining Airflow

## Air Duct Calculator | Rectangular Duct

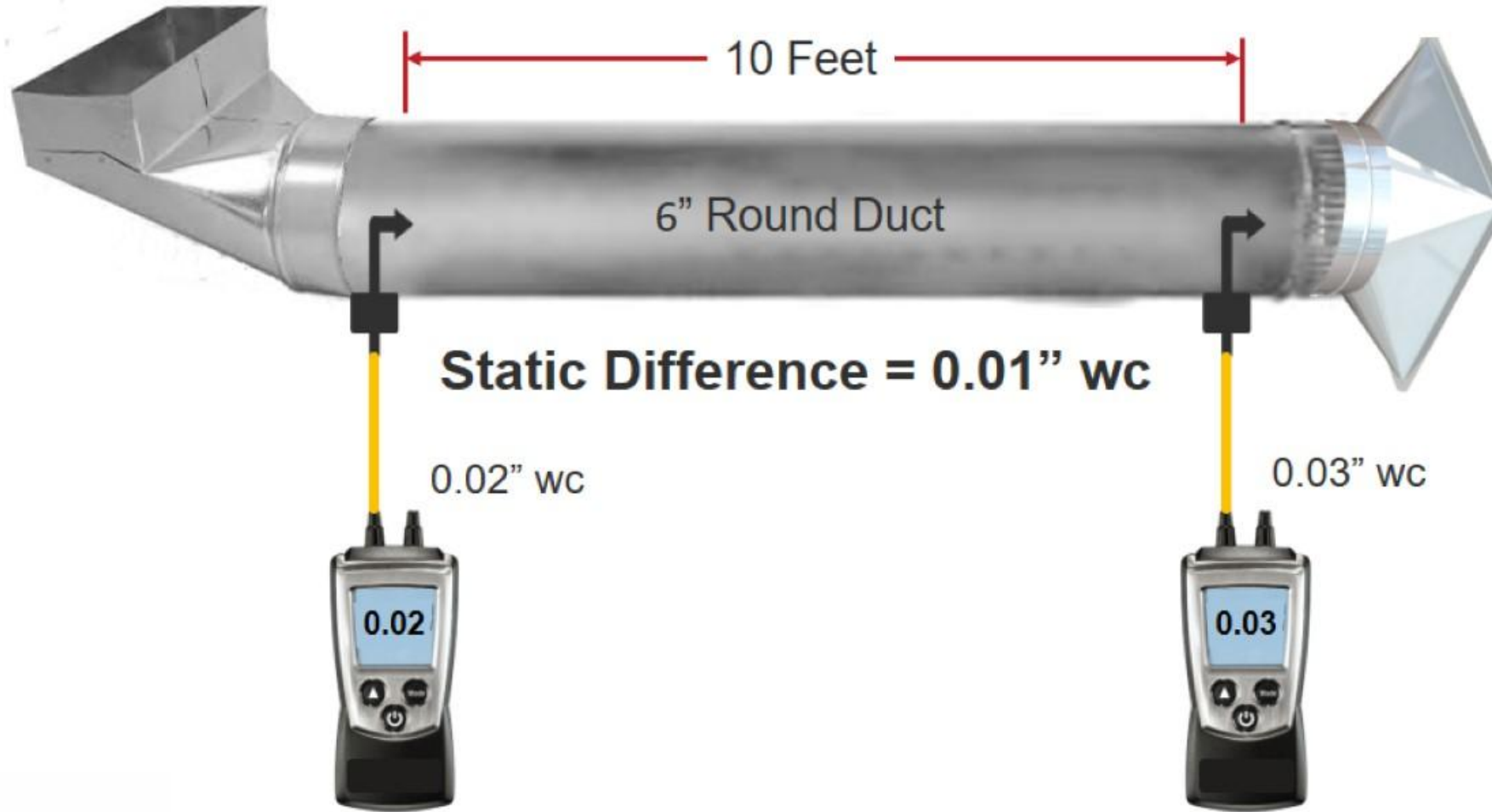


# Determining Airflow

## Air Duct Calculator | Maximum Duct Velocities

<b>RECOMMENDED AND MAXIMUM DUCT VELOCITIES</b>						
<b>DESIGNATION</b>	<b>(MAXIMUM VELOCITIES SHOWN IN PARENTHESIS)</b>					
	<b>RESIDENCES</b>		<b>SCHOOLS, THEATERS, PUBLIC BUILDINGS</b>		<b>INDUSTRIAL BUILDINGS</b>	
	<b>THESE VELOCITIES ARE FOR TOTAL FACE AREA</b>					
Outdoor Air Intakes	500	(800)	500	(900)	500	1200)
Filters	250	(300)	300	(350)	350	(350)
Heating Coils	450	(500)	500	(600)	600	(700)
Cooling Coils	450	(450)	500	(500)	600	(600)
Air Washers	500	(500)	500	(500)	500	(500)
	<b>FOLLOWING VELOCITIES ARE FOR NET FREE AREA</b>					
Fan Outlets	1000-1600	(1700)	1300-2000	(1500-2200)	1600-2400	(1700-2800)
Main Ducts	700-900	(800-1200)	1000-1300	(1100-1600)	1200-1800	(1300-2200)
Branch Ducts	600	(700-1000)	600-900	(800-1300)	800-1000	(1000-1800)
Branch Risers	500	(650-800)	600-700	(800-1200)	800	(1000-1600)

# Determining Airflow



# Determining Airflow

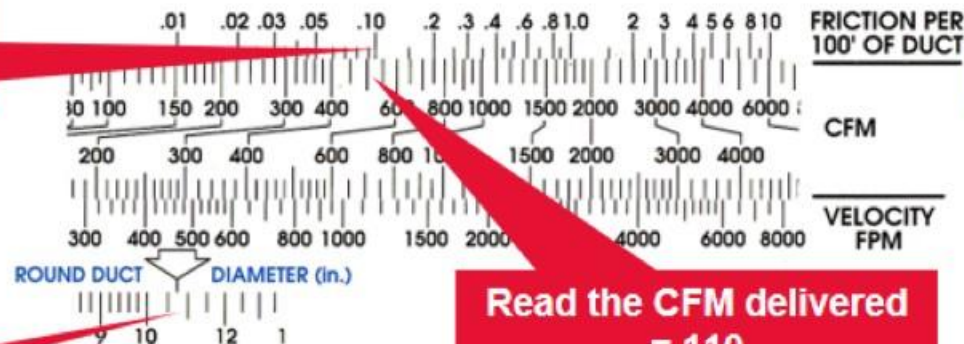
## Air Duct Calculator

Find the measured static pressure loss per 100' = 0.10" wc

Accomplish the following, all with one setting:

- Friction
- Velocity - F.P.M.
- Round Duct Size
- Weight Per Lin. Ft. Of Round Duct
- Surface Area In Sq. Ft. Per Lineal Foot Of Round Duct
- Rectangular Equivalents Of Round Duct Sizes

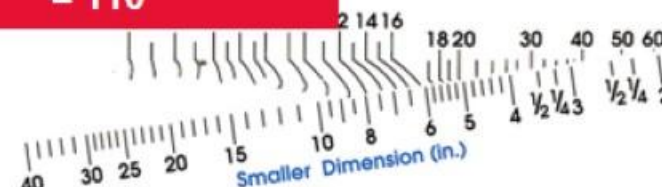
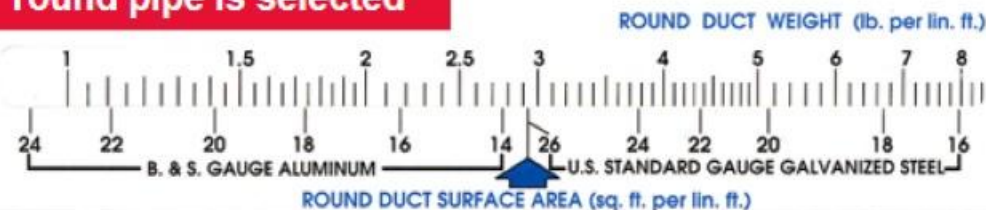
Move duct slide until 6" round pipe is selected



Read the CFM delivered = 110

### EQUAL-FRICTION METHOD

- 1) Set CFM under FRICION and read VELOCITY below CFM.
- 2) Read ROUND DUCT DIAMETER at arrow.
- 3) Select EQUIVALENT RECTANGULAR DUCT and read ROUND DUCT WEIGHT opposite appropriate GAUGE.
- 4) Read SURFACE AREA at blue arrow.

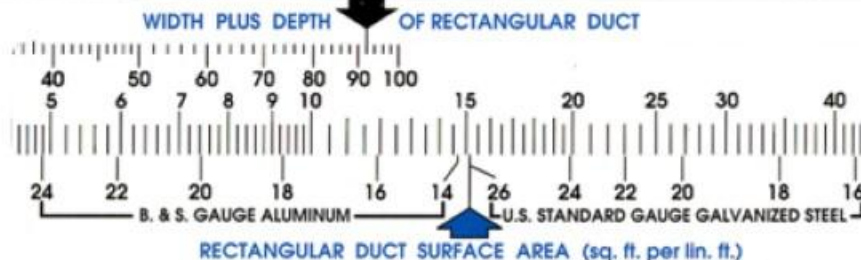


### VELOCITY-REDUCTION METHOD

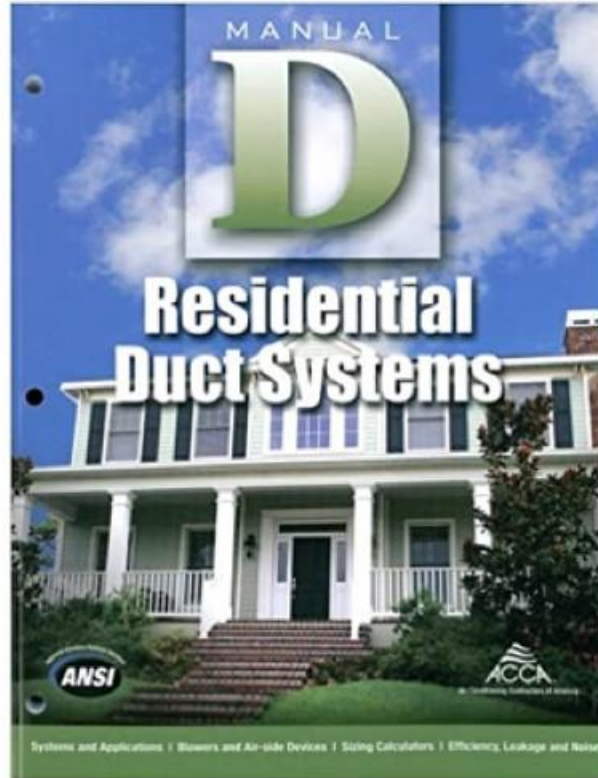
- 1) Set CFM at VELOCITY and read FRICION above CFM.
- 2) Read other data as instructed under EQUAL-FRICTION.

### WIDTH PLUS DEPTH

- 1) Set total of WIDTH PLUS DEPTH OF RECTANGULAR DUCT at black arrow.
- 2) Read RECTANGULAR DUCT WEIGHT opposite appropriate GAUGE.
- 3) Read SURFACE AREA at blue arrow.



# Module 5



## Proper Duct Design

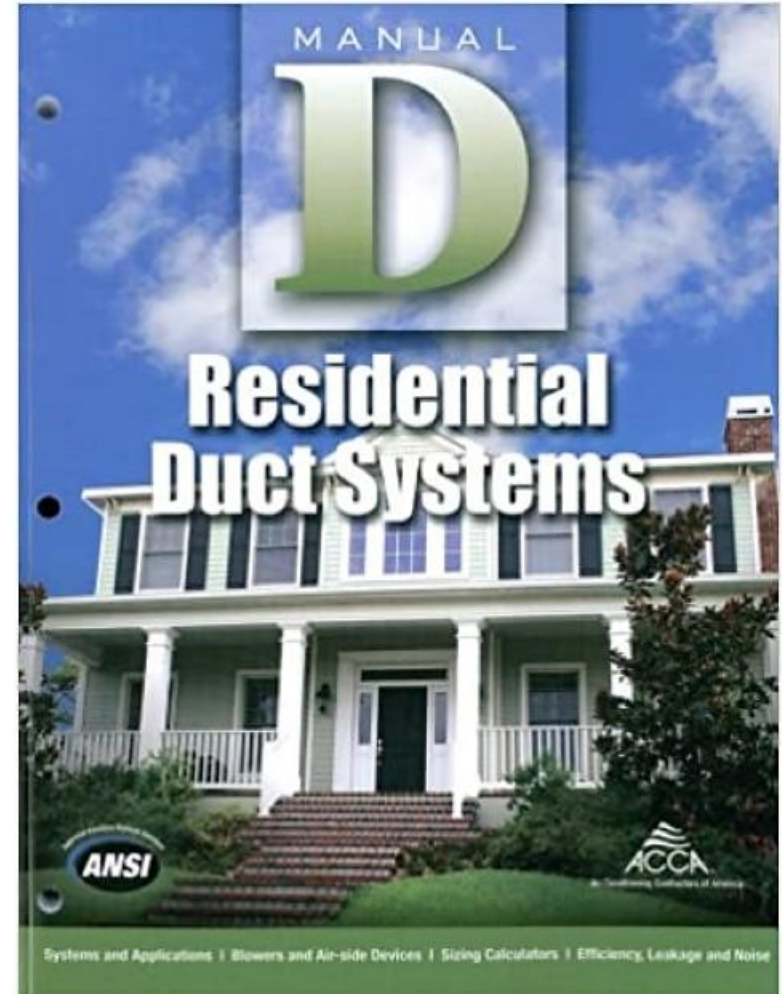
### Learning Objectives

- Discuss the proper methods for determining an improper duct system utilizing Manual D<sup>®</sup> – Residential Duct Systems

# Proper Duct Design

## Why are duct design calculations important?

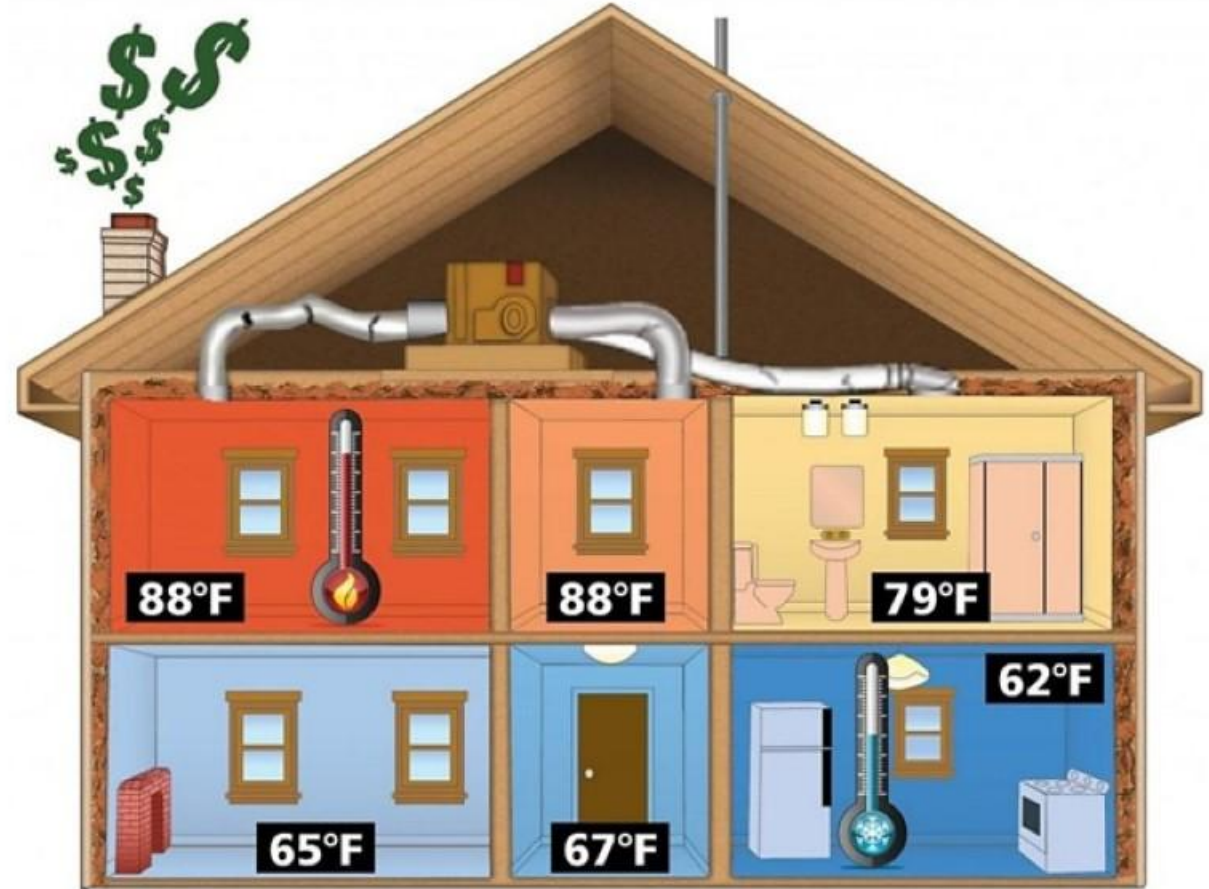
- Achieving occupant satisfaction is the principal goal of any HVAC design.
- For residential air duct designs, ACCA's Manual D<sup>®</sup> is the procedure recognized by the American National Standards Institute (ANSI) and specifically required by residential building codes.



# Proper Duct Design

## What problems come from wrong sized ducts?

- If the network of ducts carrying the air are not properly designed:
  - Health and safety of occupants are at risk
  - Occupant comfort might be sacrificed
  - Equipment could fail more quickly
  - Energy costs could rise
  - Poor air distribution
  - Inconsistent Room Temperatures
  - Airflow Noise



# Proper Duct Design

## Manual D<sup>®</sup> Residential Duct Design Checklist

ACCA Manual D<sup>®</sup> provides a checklist of important items which includes:

- A – Correct airflow at specified static pressure
- B – Published fan performance data
- C – Accessory and device pressure losses
- D – Ductwork sized using total equivalent length
- E – Friction rate design value
- F – CFM for each room
- G – Branch lead sizing
- H – Return trunk duct velocities
- I – Register and grill face velocities

ACCA's Manual D Residential Duct Design Checklist		
Key Item	Check	Questions to Ask
Information from load calculation	CFM for each room	Does each room have a heating and cooling CFM assigned? (Proportioned air supply based on Manual J8 room-by-room load calculations) <b>F</b>
Manufacturer's Data	Manufacturer's External Static Pressure (ESP)	According to the manufacturer's data will the fan produce the specified airflow at the specified static pressure? (Manufacturers produce a graph that relates air flow and static pressure) <b>A</b> <b>B</b>
	Accessory and device pressure losses	Did the contractor submit the manufacturer's data specifying the pressure drop for any item in the air stream like a high efficiency filter or a hot water coil? <b>C</b>
Manual D Friction Worksheet	Available Static Pressure (ASP)	Are supply outlets, return grilles, and balancing dampers listed at a standard 0.03? Are the pressure drops listed for other external devices: filters, coils, etc...? <b>C</b>
	Total Effective Length (TEL)	Did the contractor calculate the TEL by adding the longest Supply Total Effective Length and the longest Return Total Effective Length? (Total Effective Length = the length of the duct from outlet back to unit + the effective length for all fittings, i.e., elbows, reducers, take-offs, etc...) <b>D</b>
	Friction Rate design value	Did the contractor use the Friction Rate Chart or calculate Friction Rate [FR = ASP x 100 / TEL] <b>E</b>
Air Distribution System Design	Branch Lead Size	Did the contractor size the ducts based on the design CFM, friction rate, and the duct material used? <b>G</b>
	Trunk Size	Did the contractor select a supply trunk duct large enough to accommodate all the supply branch leads?
	Return Trunk Duct Velocities	Did the contractor select the return trunk duct large enough to meet the lower return air velocity requirements? <b>H</b>
	Return air path	Verify each occupied room has an open air path (ACCA recommends a ducted return for each bedroom, den, library, etc...)
Manual T	Register and Grille Face Velocities	Does the air velocity across the register or grille exceed the Recommended Velocity Chart? (Grille manufacturers list the face velocity for grilles and registers at a given CFM, e.g., 12 x 4 - Model XYZ, 500cfm at 120cfm) <b>I</b>

# Proper Duct Design

## Manual D<sup>®</sup> Residential Duct Design Worksheets

ACCA Manual D<sup>®</sup> has several worksheets to assist with designing a proper duct system including:

- Friction Rate Worksheet
- Air Distribution and System Design Information

### Friction Rate Worksheet

Step 1) Manufacturer's Blower Data  
External Static Pressure (ESP) = 0.70 IWC CFM= 1200 CFM

Step 2) Device Pressure Losses (DPL)

Direct expansion refrigerant coil.....	0.23 IWC
Electric heat resistance coil.....	_____
Hot water coil.....	_____
Fiber.....	0.18 IWC
Humidifier.....	_____
Supply outlet.....	0.03 IWC
Return grille.....	0.03 IWC
Balancing dampers.....	0.03 IWC
Other device.....	_____
<b>Total device losses.....</b>	<b>0.50 IWC</b>

Step 3) Available Static Pressure (ASP)  
ASP = ESP - DPL (Step 1 - Step 2) = 0.20 IWC

Step 4) Total Effective Length (TEL)  
Supply side TEL + Return side TEL = 200 ft TEL

Step 5) Friction Rate Design Value [FR= (ASPx100)/TEL] 0.10 IWC from chart below

### Table of Useful Air Distribution System Design Information

Zone:	<u>One</u>	Design Friction Rate:	<u>0.10</u>	Type of System:	<u>Trunk and Branch</u>
Construction Material	Supply Air Trunk	<u>Metal</u>	Supply Air Branch	<u>Flex</u>	
Construction Material	Return Air Trunk	<u>Duct board</u>	Return Air Branch	<u>Flex</u>	
R-Value of Insulation	Supply	<u>R6</u>	Return	<u>R6</u>	
Room	Design CFM	Supply Duct Size(s)	Supply Grille(s) Size, and Velocity	Return Duct Size(s)	Return Grille Size and Velocity
Bedroom 1	150	1 - 8"	1 - 14x6, 600fpm	(9") - 12"	14x14, 300fpm
Walk-in-Closet	15	1 - 4"	1 - 8x4, 450fpm		
Bedroom 2	100	2 - 6"	2 - 10x4, 600fpm	(7") - 8"	14x8, 275fpm
Bedroom 3	100	1 - 7"	1 - 12x4, 600fpm	(7") - 8"	14x8, 275fpm
Living Room	275	2 - 8"	2 - 14x6, 575fpm	(16") - 18"	24x24, 350fpm
Den	125	1 - 8"	1 - 14x6, 600fpm		
Dining	125	2 - 6"	2 - 10x4, 600fpm		
Foyer	80	1 - 6"	1 - 10x4, 600fpm		
Bath 1	65	1 - 6"	2 - 10x4, 625fpm		
Bath 2	90	1 - 5"	1 - 10x4, 600fpm		
Bath 3			1 - 8x4, 500fpm		
<b>TOTALS</b>	<b>1200</b>				

Notes:  
Types of Supply System: Trunk and Branch, Perimeter Loop, Radial  
Construction Materials: Sheet metal, Fiberglass Ductboard, Rigid Round Fiberglass, Flexible Vinyl Duct, Fiberglass Duct Liner w/ Facing, Flexible Metal Duct

### Recommended Velocity (FPM) (Manual D, Table 3-1)

	Supply				Return			
	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	450	700	700
Supply Outlet Face Velocity	Size for Throw			700				
Return Grille Face Velocity					500			
Filter Grille Face Velocity					300			

**I** Grille and register sizes should be selected to ensure the velocities are acceptable.

**H** The return duct size is based on the friction rate and then may be adjusted to a larger size to meet recommended velocity.

**G** The Friction Rate is used to determine the duct size.

**E** Friction Rate is found by reading bottom scale to 0.20 and up the side scale to 200 feet the intersecting line is the 0.10. That is the design friction rate. This example, 0.10, is within the acceptable friction rate range.

**D** Total Effective Length = loss from duct lengths, reducers, elbows and other fittings

**C** From Manufacturer's Performance Data

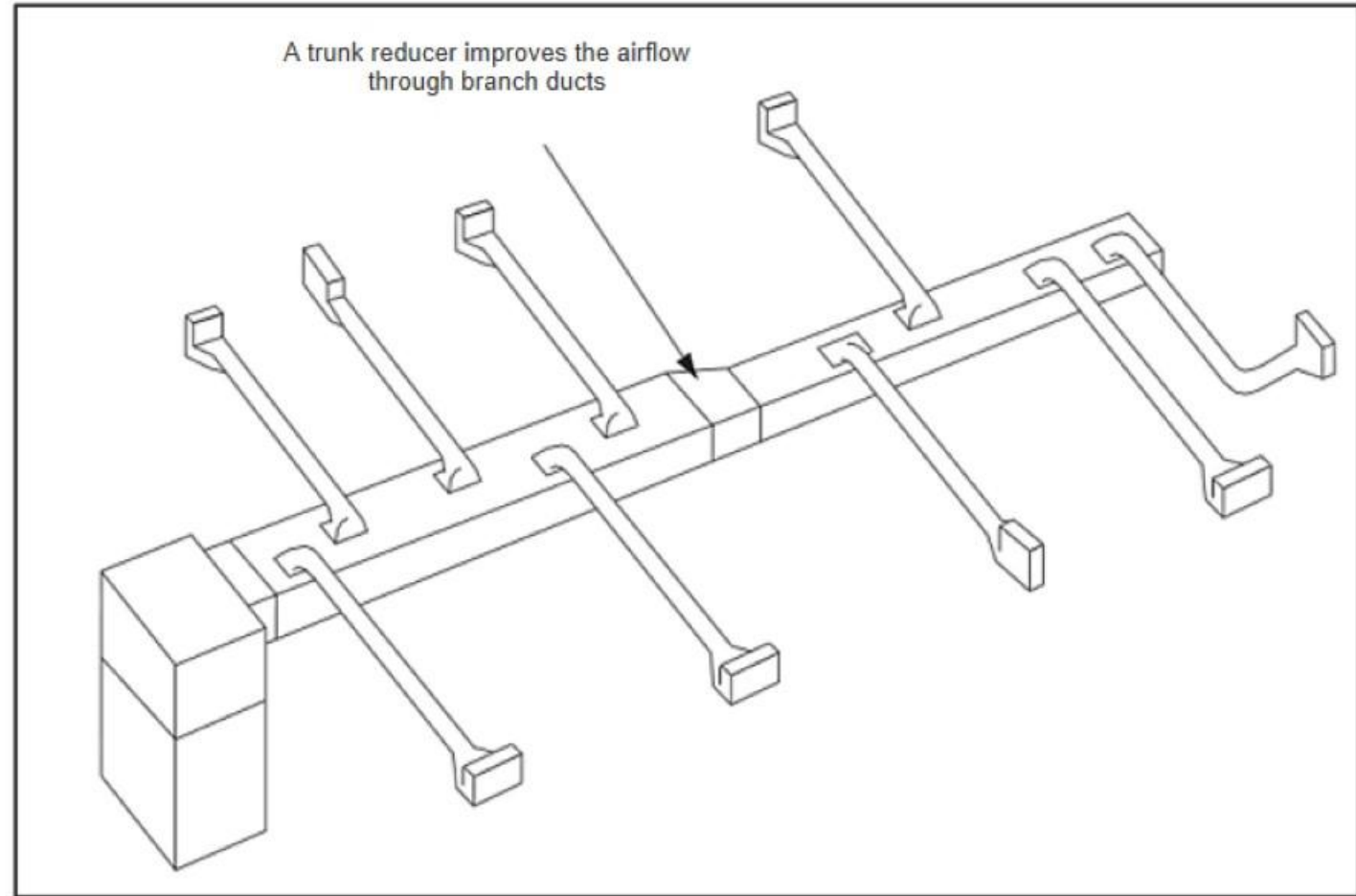
**B** From Manufacturer's Blower Performance Data corresponding to the CFM

**A** From manufacturer's data—equipment CFM at rated capacity

# Proper Duct Design

## Reducing Trunk Duct System

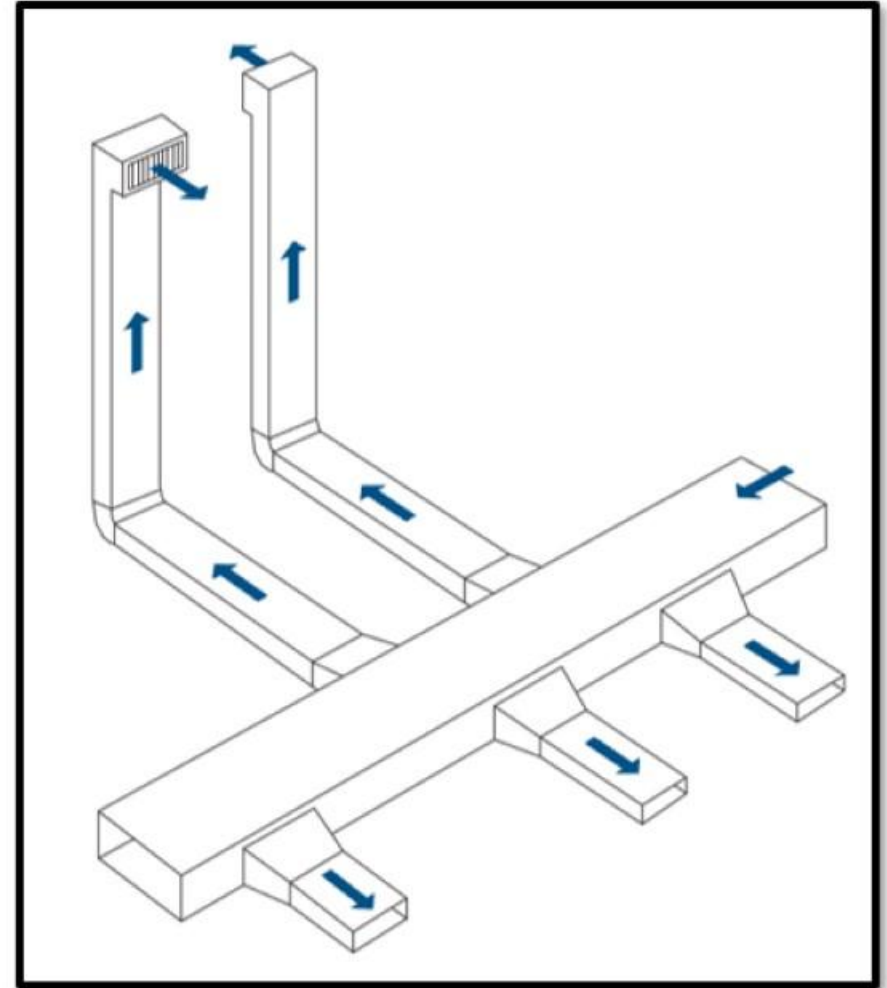
- Characteristics of a tree trunk
- Provides good control of separate airstreams
- Usual depth is 8" or 10"
- Branch take-offs may be round or rectangular



# Proper Duct Design

## Extended Plenum Duct System

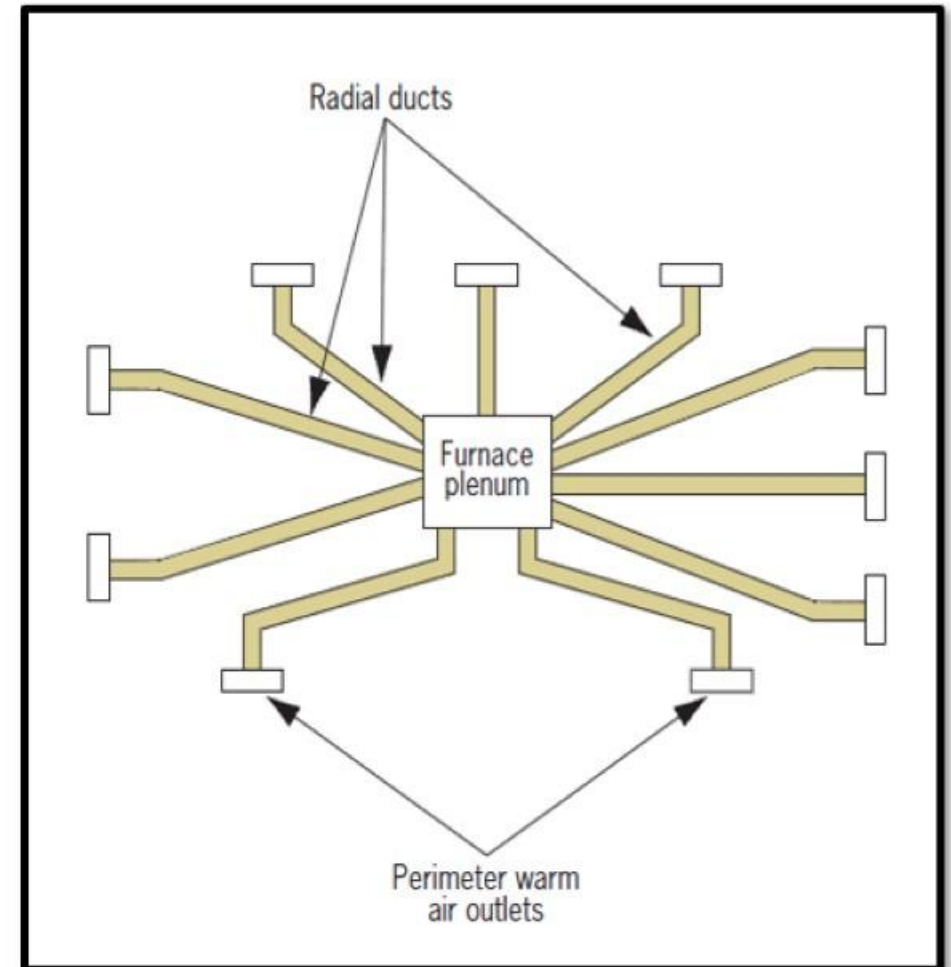
- Trunk duct does not vary in size
- Trunk may be assembled in the shop in sections
- More sheet metal used
- Offers labor savings
- Side and top take-offs are used
- Not for use in larger homes



# Proper Duct Design

## Perimeter Radial Duct

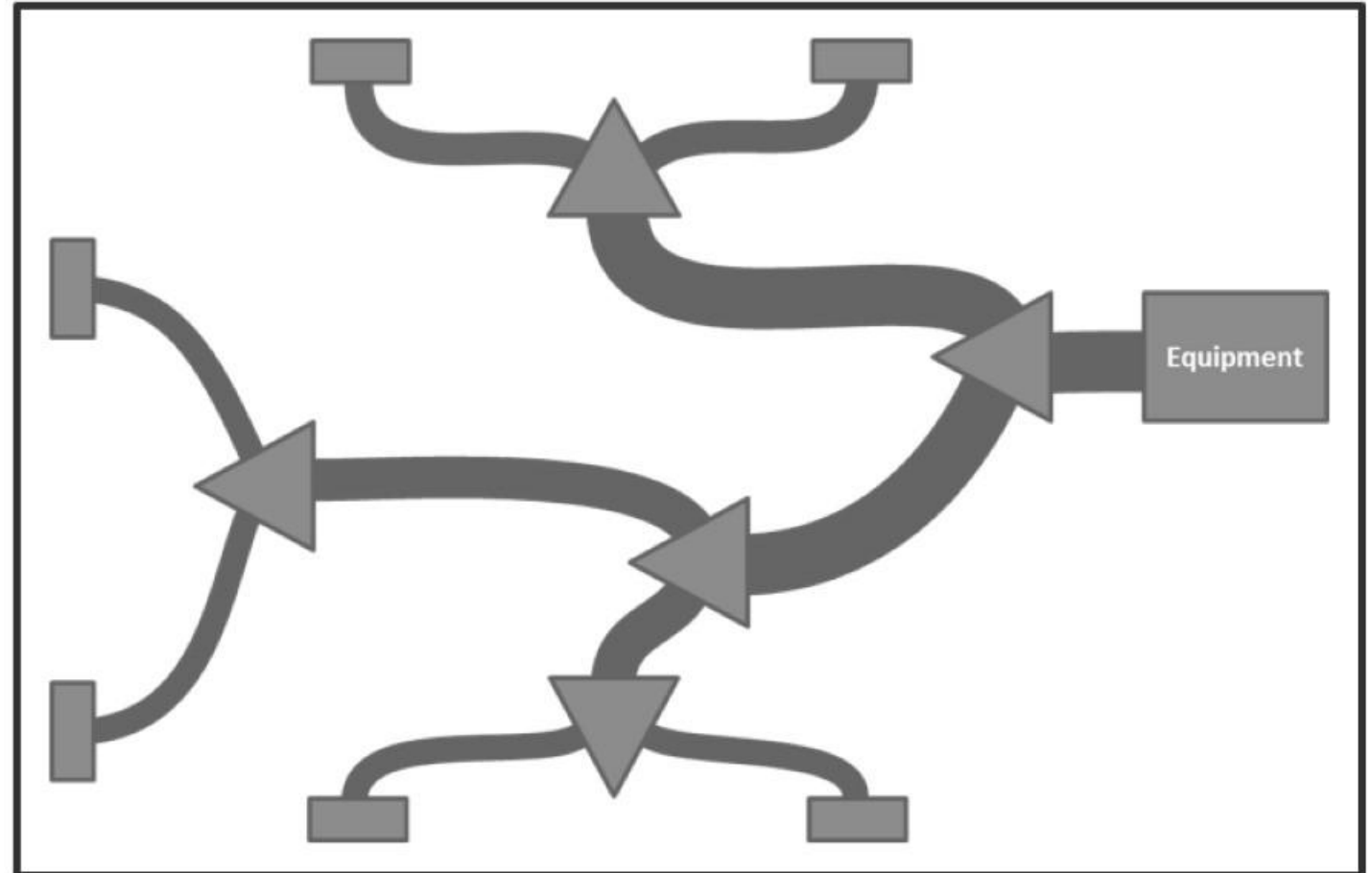
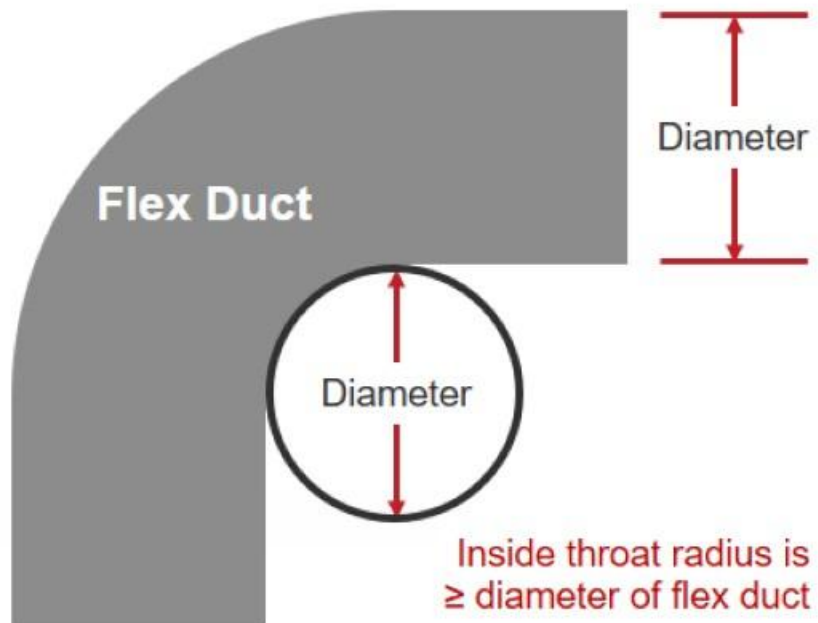
- Registers located in the floor or baseboard along outer walls
- No trunk duct
- Easy to design and install
- Home applications:
  - Slab-built
  - Crawlspace
  - Basement



# Proper Duct Design

## Flex Duct Spider System

- Duct should be pulled as tight & straight as possible
- Turns in flexible duct must have a minimum of 1 duct diameter

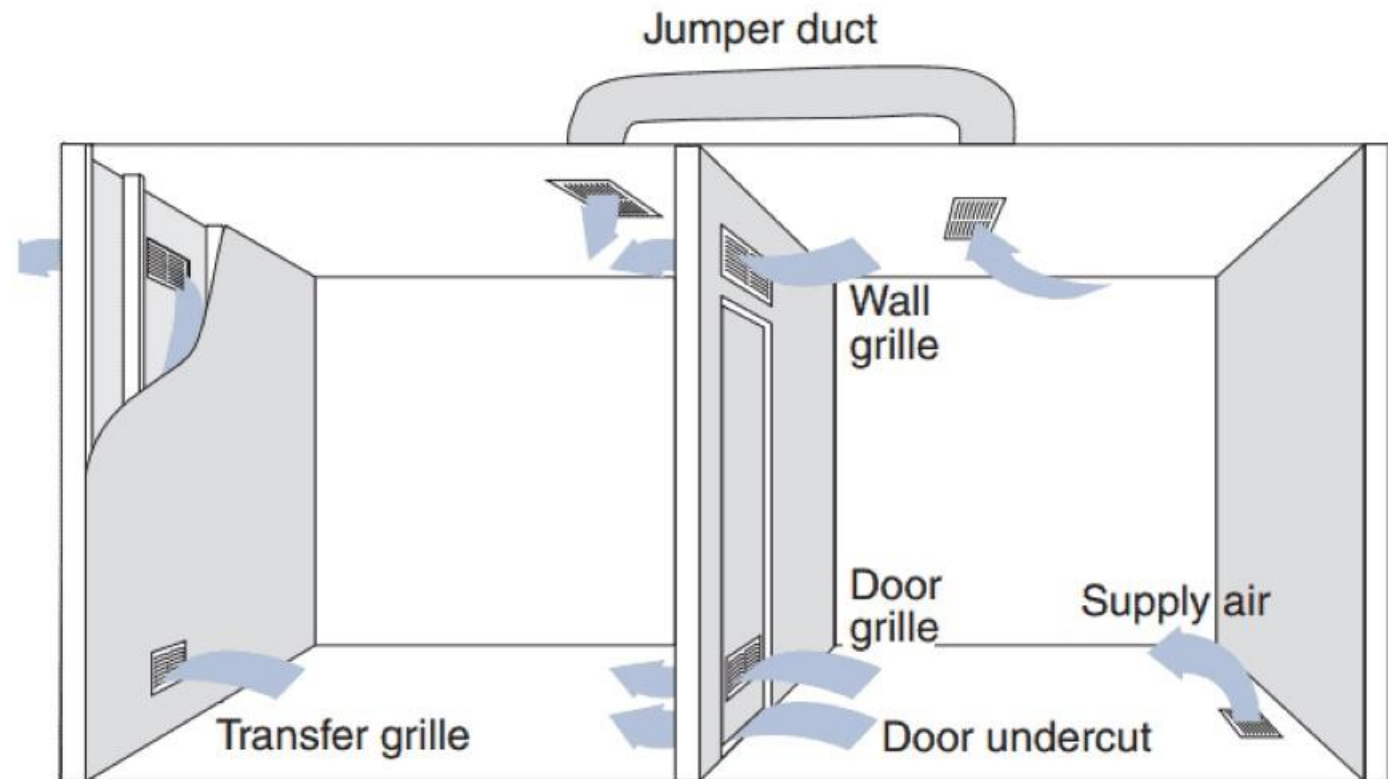


# Proper Duct Design

## Pressure Balancing

Jump ducts or transfer grilles should be installed in all rooms that have closed doors when a common return is used.

- Reduces the chance of combustion appliances back drafting
- Provides free flow of conditioned air
- Relieves room pressure



<b>Door Cut Height for 300 FPM Air Velocity</b>							
<b>CFM Under Door</b>	<b>Door Width (Inches)</b>						
	24	30	36	42	48	54	60
	<b>Clearance (Inches) to floor or Top of Carpet</b>						
<b>100</b>	2.0	1.6	1.3	1.1	1.0	0.9	0.8
<b>200</b>	4.0	3.2	2.7	2.3	2.0	1.8	1.6
<b>300</b>	6.0	4.8	4.0	3.4	3.0	2.7	2.4
<b>400</b>	8.0	6.4	5.3	4.6	4.0	3.6	3.2
<b>500</b>	10.0	8.0	6.7	5.7	5.0	4.4	4.0
<b>600</b>	12.0	9.6	8.0	6.9	6.0	5.3	4.8
<b>700</b>	14.0	11.2	9.3	8.0	7.0	6.2	5.6
<b>800</b>	16.0	12.8	10.7	9.1	8.0	7.1	6.4
<b>900</b>	18.0	14.4	12.0	10.3	9.0	8.0	7.2
<b>1000</b>	20.0	16.0	13.3	11.4	10.0	8.9	8.0
<b>1200</b>	24.0	19.2	16.0	13.7	12.0	10.7	9.6
<b>1400</b>	28.0	22.4	18.7	16.0	14.0	12.4	11.2
<b>1600</b>	32.0	25.6	21.3	18.3	16.0	14.2	12.8

# Proper Duct Design

## Duct Through Unconditioned Space

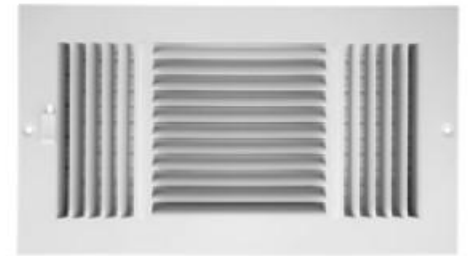
- Running supply or return ductwork through an unconditioned space such as an attic or crawl space may cause conditioned air to lose desired qualities:
  - Cooled air picks up heat
  - Heated air becomes cooled
- Insulation is required when a temperature difference of greater than 15°F exists between the outside and the inside of the duct:
  - Flex duct and duct board have built-in insulation
  - Metal duct may be insulated inside or outside:
    - Internal insulation adds resistance to air movement



# Proper Duct Design

## Sizing a Supply

- Determine the amount of CFM (air volume) needed for each supply outlet. This should be done by room heating and cooling load requirements from various design manuals (ACCA Manual J).
  - Factors to be considered when selecting supply registers.
    - Face Velocity
    - Pressure Loss (inches of w.c.)
    - Noise



# Proper Duct Design

## Sizing a Supply (Face Velocities and Noise Criterion)

Application	Recommended Face Velocities
Broadcasting Studios	<500 FPM
Residences	500 to 750 FPM
Apartments	500 to 750 FPM
Churches	500 to 750 FPM
Hotel Guestrooms	500 to 750 FPM
Legitimate Theaters	500 to 1000 FPM
Private Offices, acoustically treated	500 to 1000 FPM
Private Offices, not treated	1000 to 1250 FPM
Motion Picture Theaters	1000 to 1250 FPM
General Offices	1250 to 1500 FPM
Stores, upper floors	1500 FPM
Stores, main floors	1500 FPM
Industrial Buildings	1500 to 2000 FPM

	Communication Environment	Typical Occupancy
< NC 25	Extremely quiet environment; suppressed speech is quite audible; suitable for acute pickup of all sounds.	Broadcasting studios, concert halls, music rooms.
NC 30	Very quiet office; suitable for large conferences; telephone use satisfactory.	Residences, theaters, libraries, executive offices, directors rooms.
NC 35	Quiet office; satisfactory for conference at a 15-foot table; normal voice 10 to 30 feet; telephone use satisfactory.	Private offices, schools, hotel guestrooms, courtrooms, churches, hospital rooms.
NC 40	Satisfactory for conferences at a 6-to 8-foot table; normal voice 6 to 12 feet; telephone use satisfactory.	General office, labs, dining rooms.
NC 45	Satisfactory for conferences at a 4- to 5-foot table; normal voice 3 to 6 feet; raised voice 6 to 12 feet; telephone use occasionally difficult.	Retail stores, cafeterias, lobby areas, large drafting and engineering offices, reception areas.
> NC 50	Unsatisfactory for conference of more than two or three persons; normal voice 1 to 2 feet; raised voice 3 to 6 feet; telephone use slightly difficult.	Computer rooms, stenographic pools, print machine rooms, process areas.

# Proper Duct Design

## Return Air Intakes

Sized and selected according to pressure and noise requirements.

- Residential Return Grilles – **ACCA**<sup>®</sup> recommends 500 fpm max for non-filter grilles.
- Residential Filter Grills – **ACCA**<sup>®</sup> recommends 300 fpm max for filter grilles.



Return Air Grille



Return Air Filter Grille

## HOW TO SIZE RETURN GRILLES

Filter Grilles  
Width x Height x 2

Flat Grilles  
Width x Height x 2.5

# Proper Duct Design

## Sizing a Return

- Air volume going back to the air handler (fan) must equal what is supplied from the air handler. Therefore, the total CFM capacity of the return grilles must equal or exceed the total CFM capacity of all supply diffusers.
  - Keep face velocity low.
  - Low velocity reduces noise, especially on stamped grilles, fixed-bar grilles can handle more velocity without noise.
- You can't really oversize a single point return like you can with a supply.
  - This does not apply to multiple return locations where balancing is more critical to pull in relevant amounts from each room.
- Static pressure is also reduced. Pressure works against & reduces blower delivery volume (CFM).

Filter Size		Area (in <sup>2</sup> )	Ton (cfm)	Filter Size		Area (in <sup>2</sup> )	Ton (cfm)
12	12	144	n/a	20	20	400	2 (800)
12	20	240	1 (400)	20	25	500	2.5 (1000)
12	24	288	1.5 (600)	20	30	600	3 (1200)
12	30	360	1.5 (600)	20	36	720	3 (1200)
14	14	196	1 (400)	24	24	576	3 (1200)
14	20	280	1.5 (600)	24	30	720	3 (1200)
14	24	336	1.5 (600)	24	36	864	4 (1600)
14	30	420	2 (800)	25	25	625	3 (1200)
16	20	320	1.5 (600)	30	30	900	4 (1600)
16	24	384	2 (800)	30	36	1080	5 (2000)

# Proper Duct Design

## Sizing a Return

- **Location**

- Returns should be put in stagnant air locations that need to be reconditioned.
  - High for cooling mode (hot air rises)
  - Low for heating mode (cold air falls)
  - Both modes, choose a primary season
- Returns should not be near a supply register's throw range. If possible, place the return at an opposite corner of the room.

- **Room Air Movement**

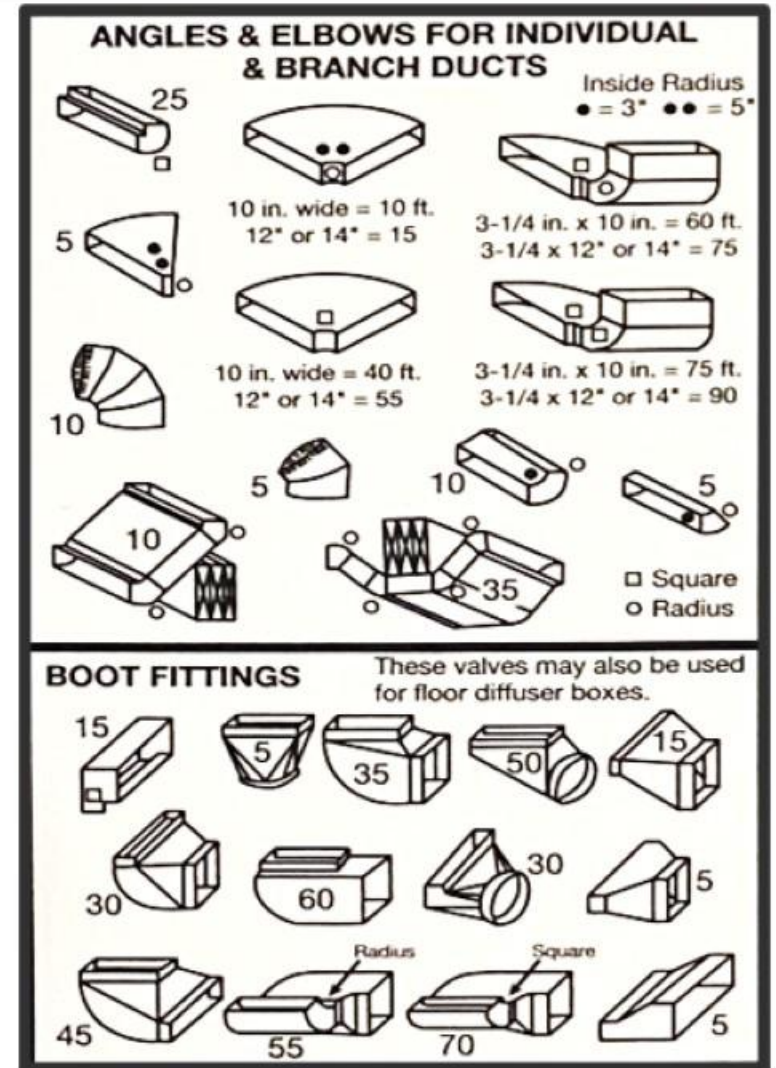
- Returns do NOT have much effect on a room's air movement, regardless of face velocity. They only grab air about a duct diameter away from the face. Most of the room air movement is done by the supplies.

# Proper Duct Design

## Equivalent Lengths

When sizing ductwork, pressure drop through fittings and elbows is expressed as equivalent feet of duct.

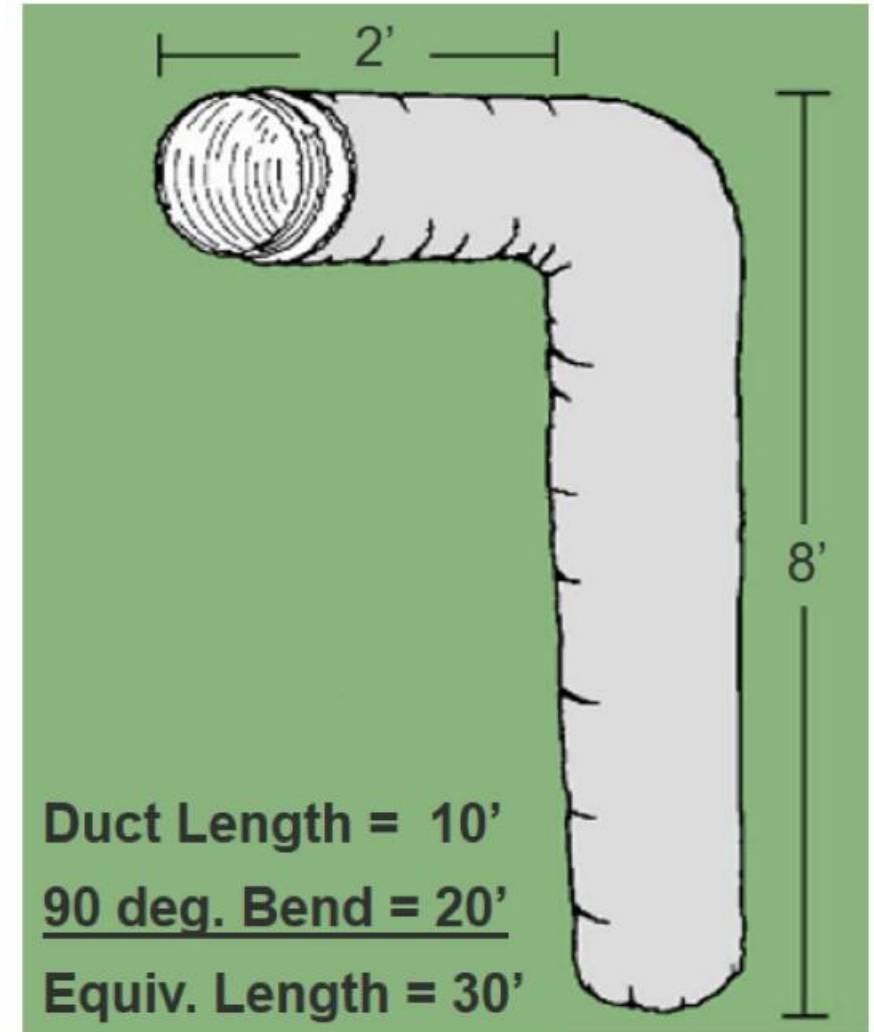
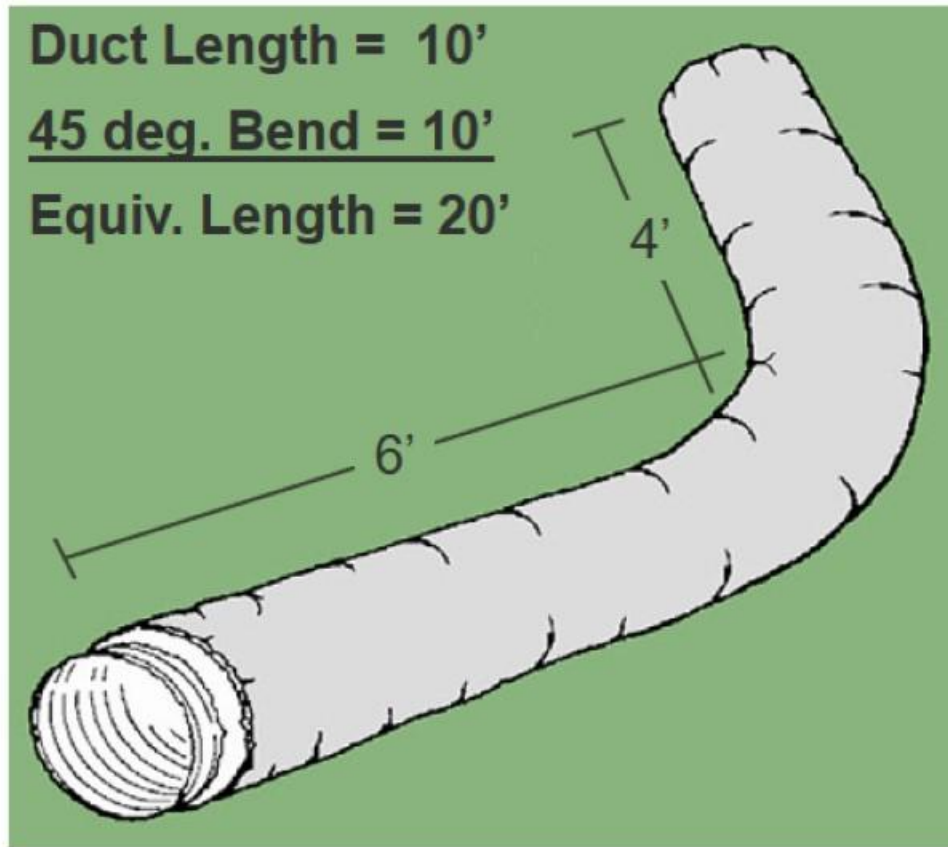
- Example = Elbow with a rating of 10 equivalent feet has same pressure drop as a 10' straight section of the same duct.
  - Manufacturers publish tables on the pressure loss of each fitting.
  - In the absence of published tables, use ACCA Manual D equivalent length values for bends and fittings.



# Proper Duct Design

## Flex Duct Equivalent Lengths

Fittings and bends in flexible duct also create additional resistance to airflow that is measured as equivalent length.



# Proper Duct Design

## Available Static

Manufacturers allow for a TESP of 0.50" wc on most residential HVAC equipment

Example:

Available static pressure (from the unit data) .....	0.50" wc
▪ Wet cooling coil .....	0.20" wc
▪ Supply register .....	0.03" wc
▪ Return Grill .....	0.03" wc
▪ Balancing Damper .....	0.02" wc
▪ Standard Filter .....	<u>0.10" wc</u>
▪ The left over is static available for 100 ft duct .	0.12" wc
▪ That must be divided between the supply and return duct system.	

# Proper Duct Design

## Airflow & Velocities

Recommended<sup>1</sup> Residential Velocity FPM @ 400 CFM per Ton (12,000 BTUs):

- Supply trunk ..... 700-900 FPM<sup>(velocity)</sup>
- Supply Branch duct ..... 600 FPM<sup>(velocity)</sup>
- Supply grill / diffuser ..... 500 FPM<sup>(velocity)</sup>
- Terminal velocity ..... 500 FPM<sup>(velocity)</sup>
- Return grill with filter ..... **300** FPM (velocity)
- Return grill No filter ..... 500 FPM<sup>(velocity)</sup>
- Return branch duct ..... 600 FPM<sup>(velocity)</sup>
- Return trunk duct ..... 600-700 FPM<sup>(velocity)</sup>

FPM is **VELOCITY** - CFM is **VOLUME**.

<sup>1</sup>Typical installed velocities are in the range of 500 to 600 FPM.

# Proper Duct Design

## Filters

- HVAC filters range from inexpensive throw away to sophisticated 4-5" media and electronic air cleaners.
- Often overlooked by the homeowner/occupant, improper or dirty filters can cause very expensive equipment failures.
- The primary purpose of a filter is to protect the HVAC Equipment.
- As velocity increases, additional dirt particles pass through the filter and pressure drop increases exponentially.



# Proper Duct Design

## What Type Filter do I use?

Select a filter with low static pressure drop @ recommended velocities.

- Verify proper grille size for AC/HP or Furnace system
- Change monthly. Filters load-up rapidly due to their design and construction and quickly restrict air flow
- Filters, even when clean, can easily use 20 to 40% of your allowable total external static pressure

Use 4" or 5" pleated media if specified!

- More surface area, extended life
- Less pressure drop than standard filters

**Remember, the filter's primary job is to protect the equipment!**

# Proper Duct Design

## Determining Filter Size

Filters are sized using required CFM and velocity

- Maximum recommended velocity on residential filters is 250 FPM (300 maximum)
- Example: 3-ton AC using 1200 CFM

$$\text{Area} = \frac{\text{CFM}}{\text{Velocity}}$$

$$\text{Area} = \frac{1200}{250}$$

$$\text{Area} = 4.8 \text{ Square Feet}$$

$$4.8 \text{ sq. ft.} \times 144 = 691 \text{ sq. in.}$$

Minimum  
area of filter = 691 sq. in

Minimum filter size  
24" X 29"

# Proper Duct Design

## Filter Pressure Drop

Pressure drop across filters will increase exponentially as velocity is increased.

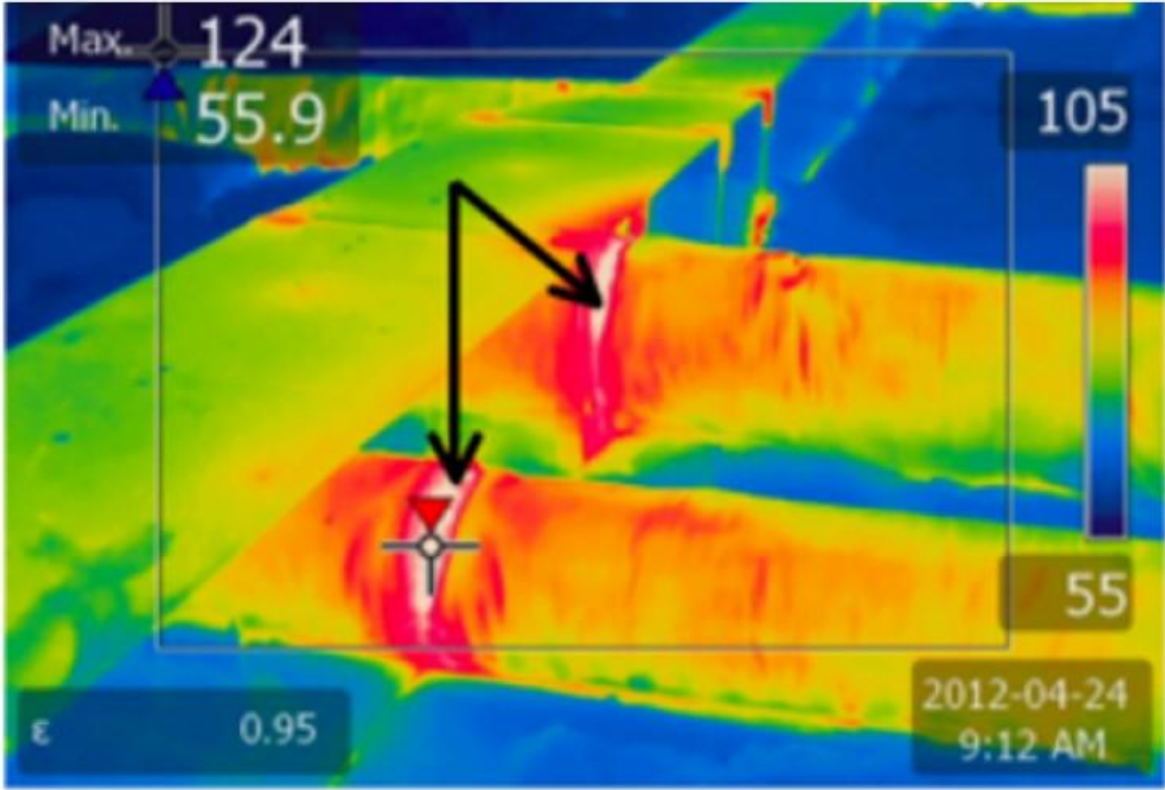
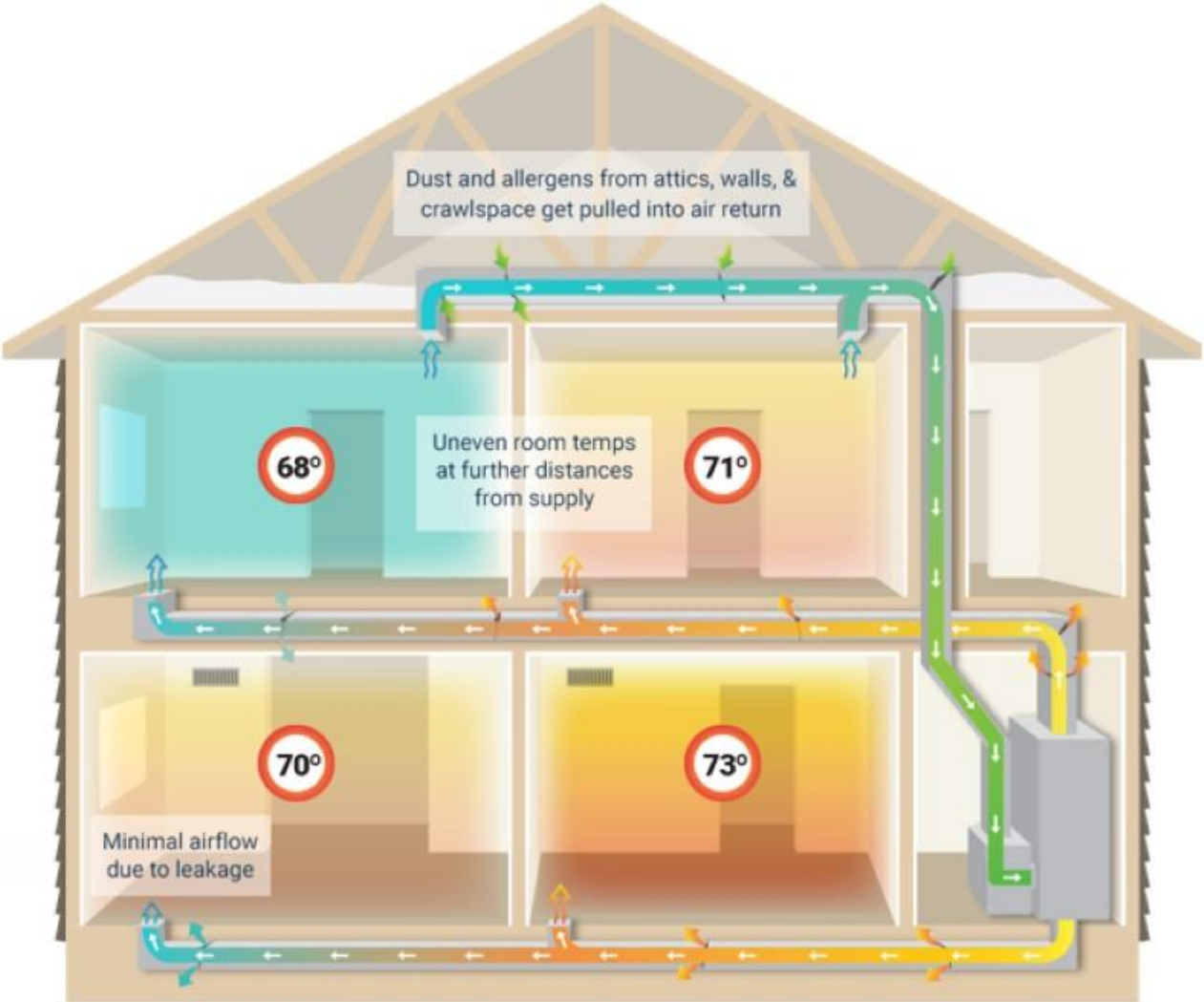
- Example:
  - Filter rated for .02" wc pressure drop @ 300 FPM
    - New velocity = 600 FPM
  - Where:
    - $V_1$  = Rated velocity (300 FPM)
    - $V_2$  = New velocity (600 FPM)
    - $PD_1$  = Rated pressure drop (0.02" wc)
    - $PD_2$  = Actual pressure drop (0.08" wc)
  - New pressure drop = 0.08" wc @ 600 FPM
    - Double the Velocity = **4 Times the Pressure Drop!**

$$PD_2 = \left(\frac{V_2}{V_1}\right)^2 \times PD_1$$

$$0.08 = \left(\frac{600}{300}\right)^2 \times 0.02$$

# Proper Duct Design

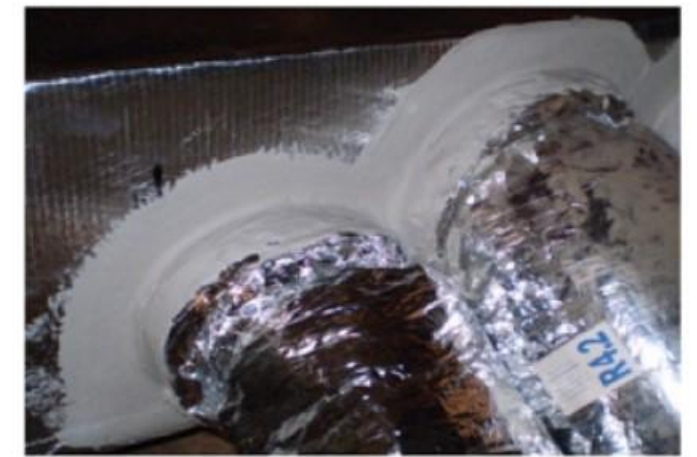
## Duct Leakage



# Proper Duct Design

## Duct Sealing Tips

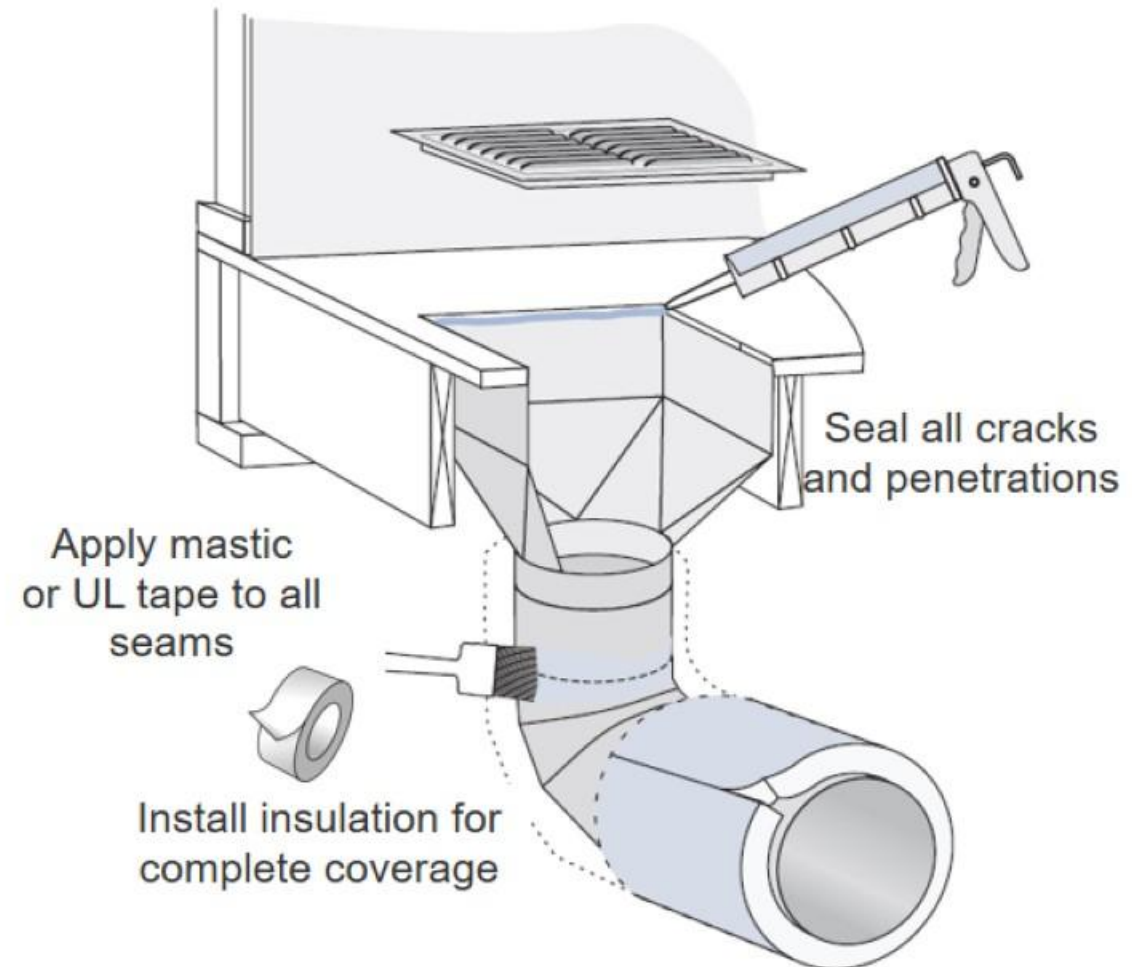
- Mastic has been used to seal duct to prevent leakage.
- There is a big difference between sealing ductwork and sealing it correctly.
- Just because you see mastic applied to a duct system, mastic in of itself does not ensure that the system is sealed.
- We see many systems where the duct sealing was only partially completed.



# Proper Duct Design

## Sealing Connections

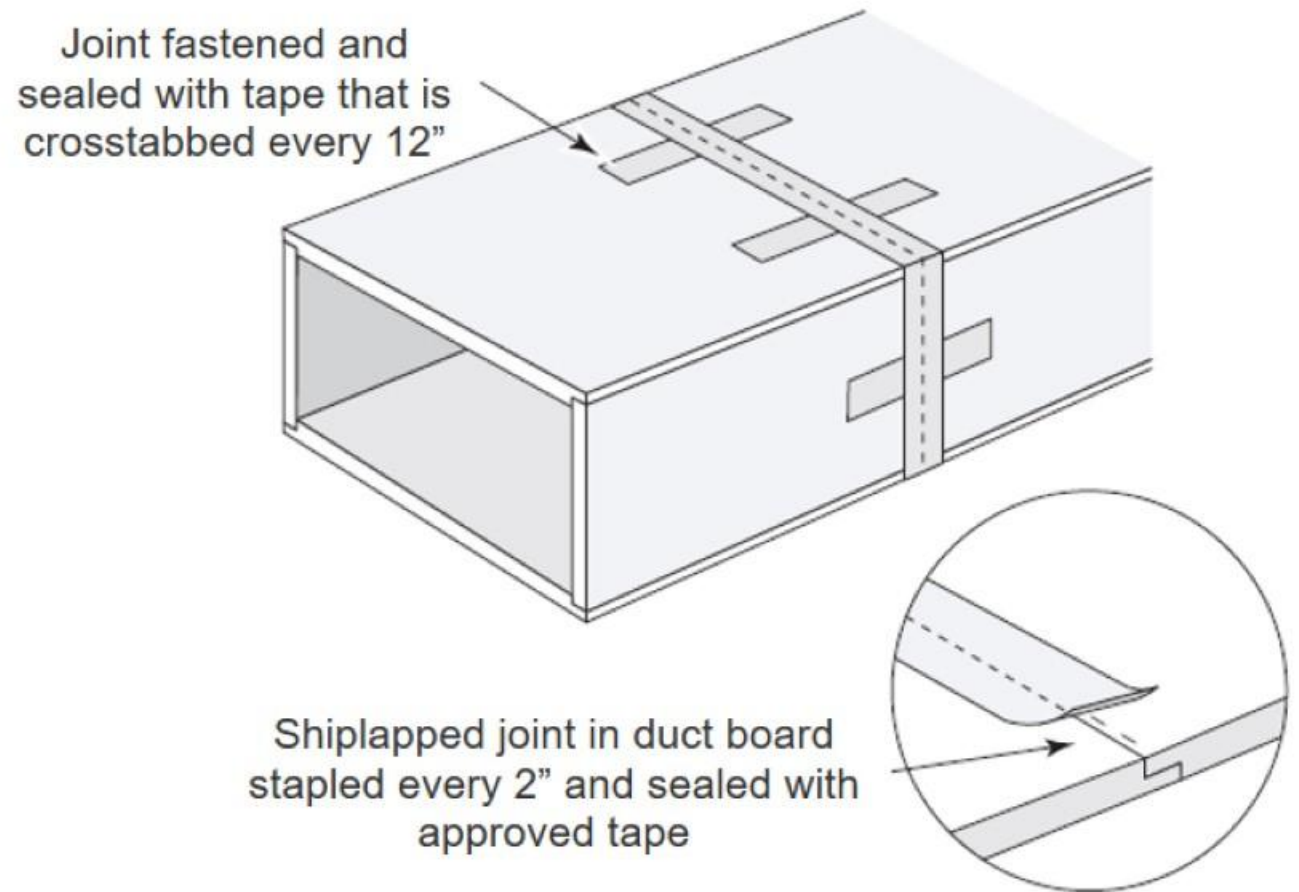
- Carefully and completely seal all duct work during construction/installation.
  - Use approved tapes or preferably mastic, because each connection, joint, and seam has potential leakage.
  - Screws should be used to mechanically fasten all joints.
  - Cracks around penetrations must be sealed.
- When located in an unconditioned space, sheet metal ducts must be insulated with either an interior duct liner or exterior insulation.



# Proper Duct Design

## Sealing Fiberglass Duct Board

- Fiberglass duct board provides excellent sound attenuation, but its longevity is highly dependent on its closure and fastening systems.
- Connections should be mechanically fastened using shiplap or V-groove joints and stapling and sealed with approved pressure-sensitive tapes and mastic.



## Aspect Ratio of Ductwork

**Aspect Ratio** compares the Height to the Width of a duct

**Example:**  
**8" X 24" Duct**  
**Aspect Ratio is 1:3**

# Proper Duct Design

## Aspect Ratio Of Round Duct

Round duct is the least restrictive.

- A 6" round duct would have a cross sectional area of about 28 square inches.
- The circumference of the duct is 18.85"
- 8' length of duct has a surface area of 1,810 square inches.



# Proper Duct Design

## Aspect Ratio Of Square Duct

A square duct is the next best

- 6" X 6" square duct has an aspect ratio of "1".
- It has a cross sectional area of 36 square inches
- The perimeter of this duct is 24"
- 8' length of duct has a surface area of 2304 square inches



# Proper Duct Design

## Aspect Ratio Of Rectangular Duct

Rectangular ducting increases friction loss:

- 3" X 12" rectangular duct has an aspect ratio of 1:4
- The cross-sectional area is also 36 square inches
- The perimeter of this duct is now 30"
- 8' length of duct has a surface area of 2880 square inches
  - Surface area increased by 20%
  - Increase in duct surface area causes additional friction and reduced airflow

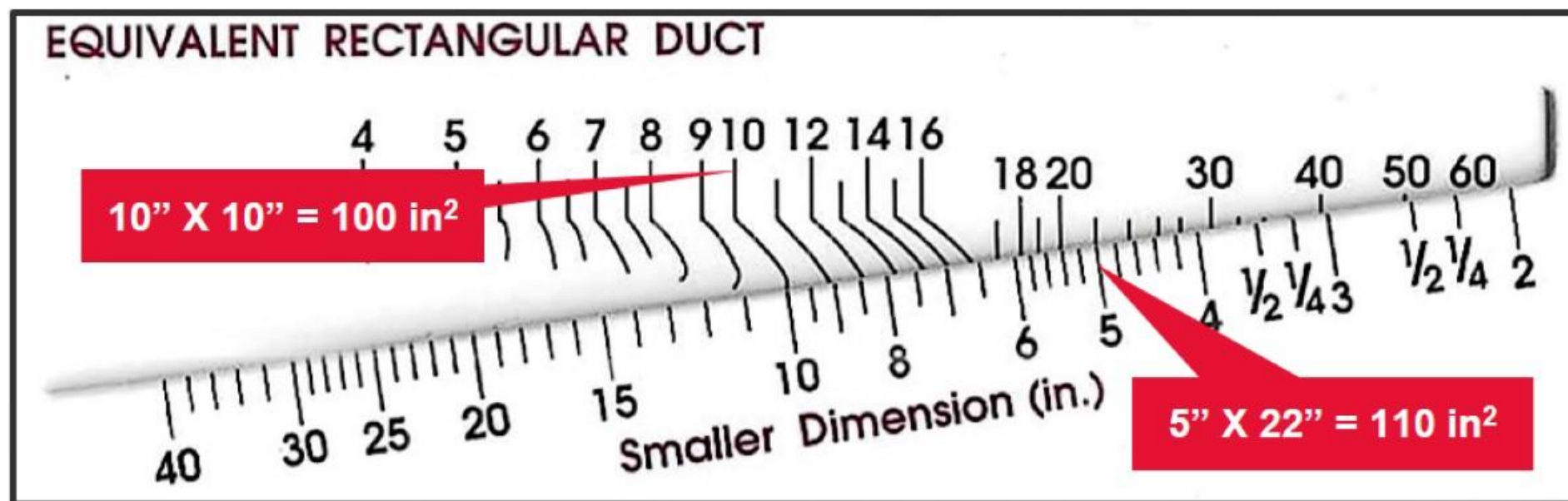


# Proper Duct Design

## Cross Sectional Area Of Rectangular Duct

As the aspect ratio increases, the cross-sectional area of the duct needed for the same performance also increases.

- 10" X 10" duct = 100 sq. in. cross-sectional area
- 5" X 22" duct = 110 sq. in. cross-sectional area

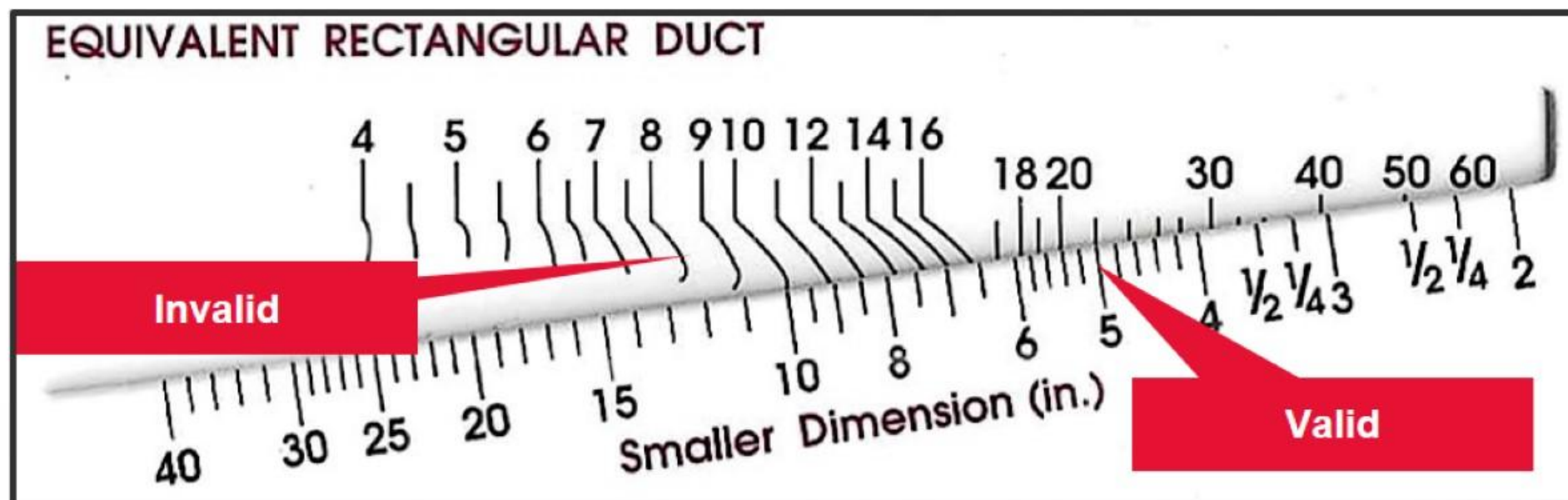


# Proper Duct Design

## Reading Rectangular Duct Size

When using a Duct Calculator care must be taken to ensure the values are read correctly.

- Smaller dimension is used on the bottom scale
- If the lines don't connect on the duct calculator it is not a valid match



# Proper Duct Design

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## Conclusion

- Accurate airflow measurements are essential when determining HVAC issues.
- Static pressure readings quickly indicate problems with the equipment or installation.
- Technicians must know the procedures for airflow testing to determine whether issues are related to the installation or to the equipment.
- ***Most HVAC issues are related to Airflow.***

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# Questions?