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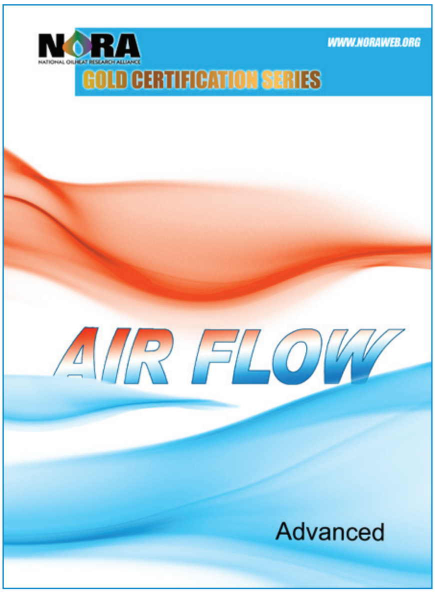
AIR FLOW

Advanced



This publication is designed to serve as a training guide and to be used in conjunction with a course taught by a qualified instructor.

The reader should use local codes and equipment manufacturer's specifications and instructions in setting up and maintaining equipment.

The editors have attempted to present accurate information, however, NORA does not make any representations or guarantees and does not assume or accept any responsibility or liability with respect thereto.

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Published by:
National Oilheat Research Alliance
600 Cameron St, Alexandria, VA 22314
NORAweb.org

9.15

Advanced Airflow

Fans and Air Flow

Airflow and the components to create it (fans, motors and ducts) move heated, cooled, or otherwise conditioned air throughout a building and return it to be treated again.

Factors that affect airflow can either positively or adversely affect system performance, efficiency and reliability. A heating or cooling system will perform no better than its air distribution system. All adequate air distribution systems must:

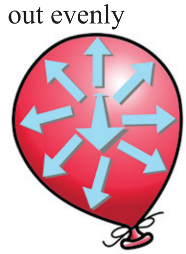
- Supply the right amount of air to each conditioned space
- Supply the air in each space so that air motion is adequate but not drafty
- Condition the air to maintain proper comfort
- Return air from all conditioned spaces
- Operate efficiently without excessive power consumption or noise
- Operate with minimum maintenance

Most air distribution systems are forced-air systems. The primary components that make up a system are the furnace, air supply system and the grilles and registers that allow the circulated air to enter the conditioned space and return it to the heating or cooling system. The air is moved through the system by the force of a fan. In older gravity systems, air was moved by heating it. Since hot air is lighter (less dense) than cold air, it rises up into the building from the heat exchanger through the supply ducts. The cooler return air, being heavier, falls back to the furnace through the return ducts.

In modern systems, air moves through ductwork because the fan creates a pressure difference in the airstream: lower pressure in the return and higher pressure in the supply. The amount of air the blower can move and the amount of energy needed to move the air is controlled by the resistance to airflow from the ductwork and all the components in the airstream. In general, fans have the highest capacity when they are in open air, without any restrictions to airflow. The capacity of the fan decreases when it moves air against a pressure difference. Such a pressure difference is created when air is constrained by ductwork. The three different pressures that exist in a duct system are static pressure, velocity pressure and total pressure.

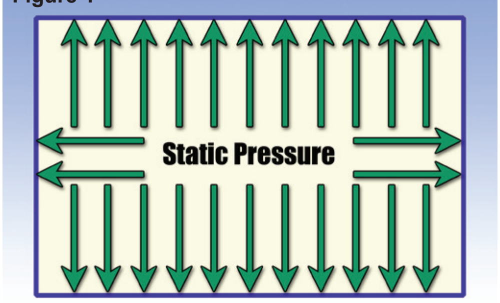
Static Pressure

The definition of the word static is “lacking in movement or change.” When a balloon is blown up, the air within pushes out evenly in all directions, creating static pressure inside the balloon, causing it to expand. The air that makes up the earth’s atmosphere has weight. It pushes down on the surface at about 14.7 pounds per square inch at sea level. This is called atmospheric or barometric pressure. The static pressure inside an inflated balloon is pushing against the atmospheric pressure outside the balloon. If the static pressure is greater than the atmospheric pressure, the balloon inflates.



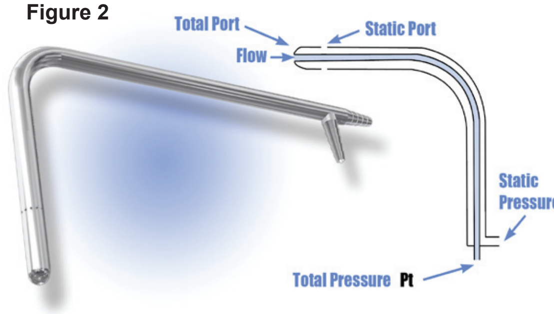
When the fan blows air into the ductwork it creates static pressure on all the interior surfaces of the ductwork. The ductwork is pressurized just like the balloon is inflated. Static pressure in the duct pushes in all directions inside the duct. This static pressure creates resistance to airflow. Figure 1.

Figure 1



Static pressure can be measured using a manometer via the static pressure openings on a pitot tube or a static pressure tip. Higher static pressure leads to lower airflow. Figure 2.

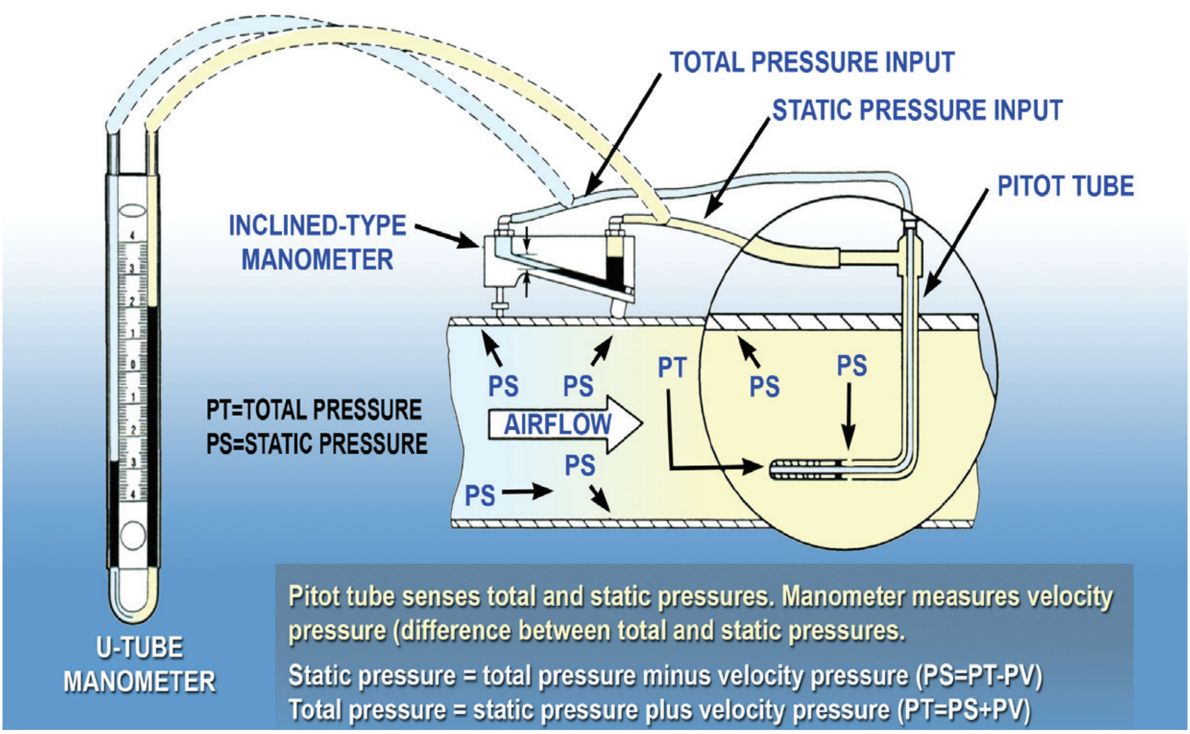
Figure 2



Velocity Pressure

The word velocity means speed. High pressure air always travels toward lower pressure. Velocity pressure determines the speed the air moves through the ductwork. The pressure coming out of the end of the balloon is velocity pressure. In Figure 3, a manometer is connected to show velocity pressure. As shown, the pitot tube must have its opening pointing into the airflow. (Figure 3, below)

Figure 3



Total Pressure

Total pressure is the sum of the static and the velocity pressures in the duct system. It is the pressure produced by the fan or blower.

Due to the low pressures inside a duct system, an incline manometer (Figure 4a), a digital manometer (Figure 4b) or a magnehelic type (Figure 4c) are used to measure duct static, velocity and total pressures in inches of water column (in. w.c.).

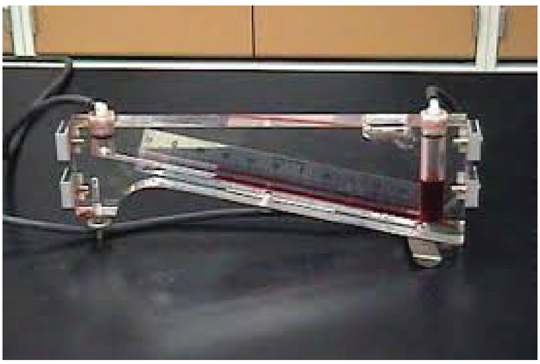
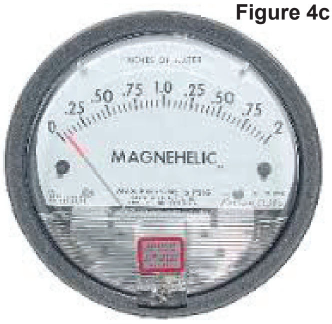


Figure 4a

Figure 4b

Figure 4c



Because the readings are very low, usually less than 0.025 pounds per square inch, we measure pressure in inches of water column. Inches of water column is the height in inches the pressure will lift a column of water; 27.7 inches of water column equals one pound per square inch. Since atmospheric pressure is 14.7 psi (14.696 psi) at sea level with 70º F dry air, this atmospheric pressure will support a column of water 33.9′ or 406.9″ high. For every one pound per square inch of pressure, a column of water will rise to a height of 27.68″ or about 2.3′.

In special low-pressure applications, such as blower door testing, pascals (pa) are used as the units of measurement. Normal pressure at sea level is 101.3 kilopascals (kPa), usually rounded to 100 kPa. To convert psi to kPa, multiply psi by 6.895. Exactly one inch of water column equals 249 pascals. As a point of reference, the typical over-the-fire draft of 0.2 inches of water column equals about 5 pascals.

Fans and Blowers

The fan or blower provides the pressure difference necessary to force the air into the supply duct, through the grilles and registers and into the conditioned space. The blower must overcome the resistance of any component in the airflow, such as: air filters, evaporator coils, heat exchangers and dampers, as well as the pressure loss involved in the return of air through the return ductwork.

The words fan and blower are often used interchangeably; however, those specific terms usually describe their function. For example, the word blower describes applications where the device must work against the resistance of a duct system, such as a forced air system. The word fan describes applications where high quantities of air are needed with little resistance to airflow, as with a condenser fan.

Two types of blowers are commonly used in heating and cooling systems: belt drive and direct drive. Belt drive blowers (Figure 5a on following page) have the blower motor mounted outside the blower housing and are connected to the blower wheel by pulleys and a belt. The blower speed is adjusted manually by a change or adjustment of the pulleys.

Increasing the size of the motor pulley will increase the rpm of the blower. Increasing the size of the blower pulley will decrease the rpm of the blower. For example, to calculate the fan rpm with a motor rpm of 1725, a 3” diameter motor pulley and a 7″ diameter fan pulley, use the following formula:

$$\text{Fan rpm} = \frac{\text{(diameter of motor pulley)}}{\text{(diameter of fan pulley)}} \text{ x motor rpm}$$

$$\text{Fan rpm} = \frac{3}{7} \text{ x } 1725$$

$$\text{Fan rpm} = .4286 \text{ x } 1725$$

$$\text{Fan rpm} = 739$$

These types of belt drive blowers (Figure 5a) were commonly used in older heating-only and commercial systems.

Direct blowers (Figure 5b) have the blower wheel mounted directly on the motor shaft. The blower speed is adjusted electrically by changing the blower motor terminals or changing the settings of the motor speed selection switches on a related motor control board. Most residential equipment uses multi-speed direct drive blowers. This enables the speed of the motor to be adjusted to match the requirements of the heating and cooling system.

Figure 5a

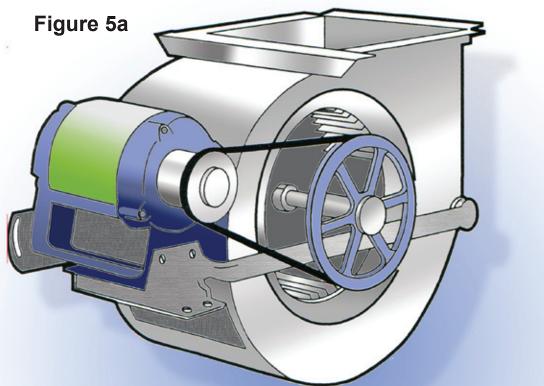
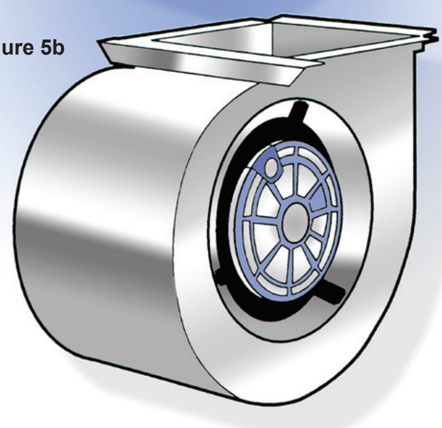


Figure 5b



ECM Blowers

Electronically Commutated Motors (ECMs) are a combination of two components, a motor control and a three phase motor with a permanent magnet rotor. The motor control is designed to operate the motor from a single phase AC power supply for residential and light commercial applications. Internally, the motor control rectifies single phase AC power to DC power, which operates the microprocessor and

ECM blowers

powers the frequency drive. The microprocessor determines the operation of the motor by controlling the output of the frequency drive. The frequency drive delivers three-phase alternating current to the motor. This design improves efficiency and range of operation compared to Permanent Split Capacitor (PSC) motors, while providing precise programming of speed, torque or airflow in HVAC/R systems.

ECMs are built in multi-speed designs with simple speed taps or communicate with an OEM control board which controls the inputs of the motor control (microprocessor).

PSC motors are not only less efficient than ECMs, they suffer efficiency loss when operated at less than their rated speed. For example, a PSC motor rated at 60% efficiency could be operating at as low as 40% efficiency when on low speed, whereas the ECM will maintain its electrical efficiency across its entire operating range. Indoor blower motor applications benefit greatly from lower continuous fan speeds where the ECM is quieter and uses up to 200% less energy than a PSC motor. Many ECMs are also built with internal protection features such as surge protection, water resistance and speed limits, which help improve motor life and reduce nuisance failures due to overheating.

Most ECMs are built with permanently lubricated ball bearings designed for long life at the wide range of operating speeds ECMs are capable of achieving. Most OEM ECMs are uniquely programmed and must be replaced with an OEM-only part.

There is a growing market for retrofit/replacement ECMs for upgrading PSC or shaded pole motors and even for replacing OEM Constant Torque applications. Some of these retrofit ECMs can also reduce truck stock with dual rotation, dual voltage and multi-horsepower features. The initial investment of an ECM driven system or retrofit may seem high, but more and more consumers are looking for energy saving alternatives, as well as comfort and health features, and that will lead you to ECMs as a logical choice.

Fan Laws

The performance of all fans and blowers is governed by three rules, commonly known as the FAN LAWS. The fan laws describe the relationships between cubic feet per minute (cfm), revolutions per minute (rpm), static pressure (s.p.) and horsepower (hp). For example, when the CFM changes, the rpm, s.p., and the hp will also change.

A fan's performance varies depending upon the conditions under which it operates. A fan that moves 400cfm of air under one condition might only move 300cfm under another condition. The amount of air a fan moves, the speed of the fan and the motor horsepower are all related. This can be proven by the fan laws:

Fan Law 1 states that the amount of air delivered by a fan varies directly with the speed of the fan. Stated mathematically,

New CFM = (new rpm x existing cfm) divided by existing rpm

or

New rpm = (new CFM x existing rpm) divided by existing cfm

Fan Law 2 states that the static pressure (resistance) of a system varies directly with the square of the ratio of the fan speeds. Stated mathematically,

New s.p. = existing s.p. x (new rpm divided by existing rpm)^2

Fan Law 3 states that the horsepower varies directly with the cube of the ratio of the fan speeds, or

New hp = existing hp x (new rpm divided by existing rpm)^3

Example:

Assume an existing system with the following conditions: 1000cfm, 825rpm, and 0.5 in. w.c. with a fan hp of 1/3hp. With an increase in airflow to 1200cfm, what are the new rpm, s.p. and hp?

Fan Law 1 calculates the new rpm:
New rpm = (1200 x 825)/1000
New rpm = 990,000/1000
New rpm = 990

Fan Law 2 calculates the static pressure:
New s.p. = .5 x (990/825)^2
New s.p. = .5 x 1.44
New s.p. = .72

Fan Law 3 calculates the horsepower:
New hp = .33 x (990/825)^3
New hp = .33 x 1.728
New hp = .57

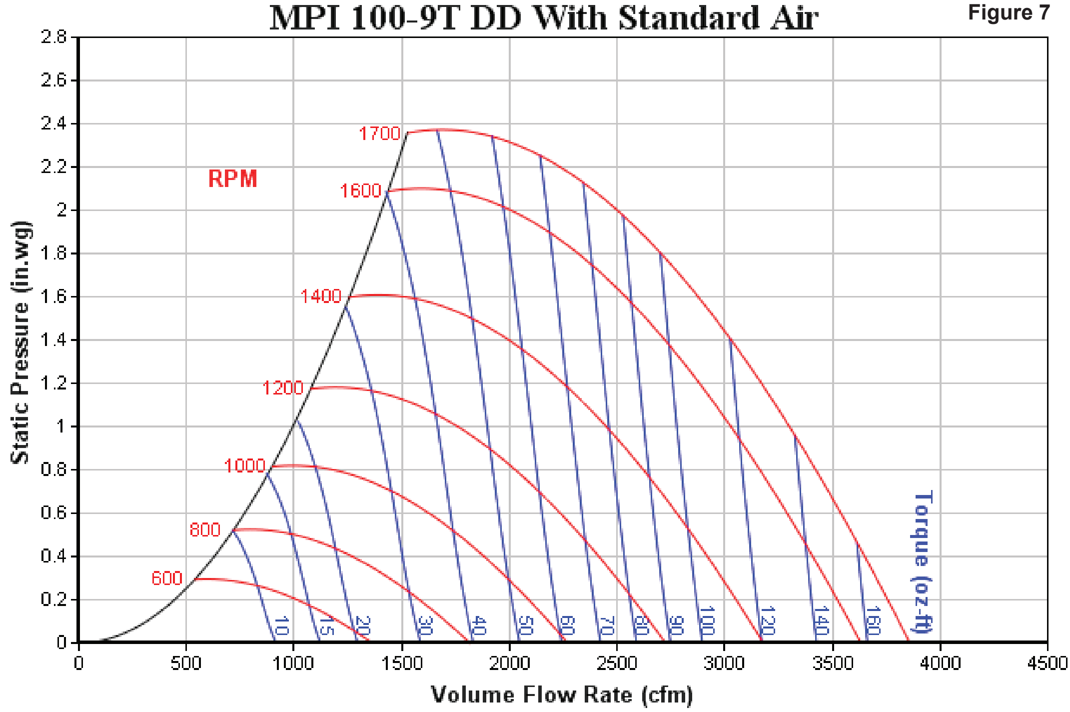
Figure 6

Regal Low Boy Direct Drive Blower Performance										
	REL 600		REL 750		REL 850		REL 1000		REL 1250	
Blower	100-10T		100-10T		100-10T		100-10T		100-10T	
Motor	3/4Hp 4 Speed		3/4Hp 4 Speed		3/4Hp 4 Speed		3/4Hp 4 Speed		3/4Hp 4 Speed	
Static Press. in W.C.	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5
CFM Hi Speed	1903	1661	1903	1661	1903	1661	2466	2072	2466	2072
CFM Med.	1711	1485	1711	1485	1711	1485	2150	1859	2150	1859
CFM Med. Lo Speed	1547	1355	1547	1355	1547	1355	1839	1610	1839	N/R
CFM Lo Speed	1399	1227	1399	1227	1399	N/R	1600	N/R	N/R	N/R
Fan Curve Page. No.	3		4		5		6		7	

Regal High Boy Direct Drive Blower Performance										
	REH 600		REH 750		REH 850		REH 1000		REH 1250	
Blower	100-10T		100-10T		100-10T		100-10T		100-10T	
Motor	3/4Hp 4 Speed		3/4Hp 4 Speed		3/4Hp 4 Speed		3/4Hp 4 Speed		3/4Hp 4 Speed	
Static Press. in W.C.	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.5
CFM Hi Speed	1745	1480	1745	1480	1745	1480	2283	2007	2283	2007
CFM Med. Hi Speed	1550	1343	1550	1343	1550	1343	2130	1832	2130	1832
CFM Med. Lo Speed	1376	1175	1376	1175	1376	N/R	1901	1644	1901	N/R
CFM Lo Speed	1250	1043	1250	N/R	1250	N/R	1717	1501	N/R	N/R
Fan Curve Page. No.	8		9		10		11		12	

MPI 100-9T DD With Standard Air

Figure 7



Fan Performance Tables

Manufacturers publish performance tables for each specific fan. Performance tables show the fan performance at specific operating conditions and the fan CFM compared to the static pressure.

Fan performance tables also include: outlet velocity, fan rpm and motor horsepower requirements for the selected condition (Figure 6). These fan performance tables can also be used to find relationships that exist for a set of system conditions involving s.p., blower/fan rpm and cfm. If you know the values for any two of the characteristics shown on the chart, you can easily find the third.

Fan Performance Curves

The fan curve is a graphical representation of the fan performance (Figure 7). Airflow is typically plotted along the x axis and power, pressure and efficiency are plotted along the y axis.

Fan curves are used in system design to select a fan capable of moving the correct amount of air at the desired operating conditions. Fan curves can also be used to predict the effect any change in operating conditions will have on fan performance. Fan curves generally show volume of air moved in CFM compared to the power delivered to the fan shaft in brake horsepower. Brake horsepower (bhp) is the measure of a motor's horsepower before the loss in power caused by the gearbox, drive train and the resistance in inches of water column.

Air Distribution Systems

Duct systems are used to distribute conditioned air throughout a building. Proper duct system design is critical to the energy efficiency of a structure. Ductwork design must include a load calculation to properly size the heating/cooling equipment and duct system. Technicians need to understand duct systems and airflow to be able to troubleshoot and maintain an HVAC system. Things that adversely affect system airflow will also have a negative effect on system efficiency and reliability.

Forced air systems distribute conditioned air in buildings. Air is heated or cooled and distributed through a duct system throughout the building. The basic components of a forced air system are the blower, the return air duct, which carries air to the blower and the supply ductwork, which carries the conditioned air to the building.

The blower provides a pressure difference in order to move air through the ductwork. The amount of air the blower can move and the energy required to move it are controlled by the resistance to airflow from the ductwork and all the components in the airstream.

Ducts create resistance to airflow, causing a pressure drop. Additionally, every component that air has to travel through creates more drops in pressure. These include filters, humidifiers, heat exchangers, evaporator coils, and the registers and grilles. The amount of pressure available to move air through the ductwork is the difference between the pressure the blower can produce and the total amount of pressure drop from the combined system components.

The four most common duct configurations are radial, reducing radial, extended plenum, and reducing extended plenum. A less common type is the perimeter loop system.

Radial Duct Systems

A radial duct system (may be referred to as an octopus system) is designed so that all the duct runs originate at the central plenum. Radial systems are frequently installed in attics but can be installed in crawl spaces, basements or slabs. Radial systems are also commonly used in small homes of 1200 square feet or less.

Figure 8

This type of system is the most economical to install. However, it usually has poor airflow performance because of static pressure losses at the furnace plenum. These losses are due to poor or too numerous duct fittings at the plenum. (Figure 8). Ductwork installed in unconditioned spaces must be insulated.

Reducing Radial Duct System

A reducing radial (Figure 9) system uses several larger ducts from the main supply plenum that feed into smaller ducts as they get closer to

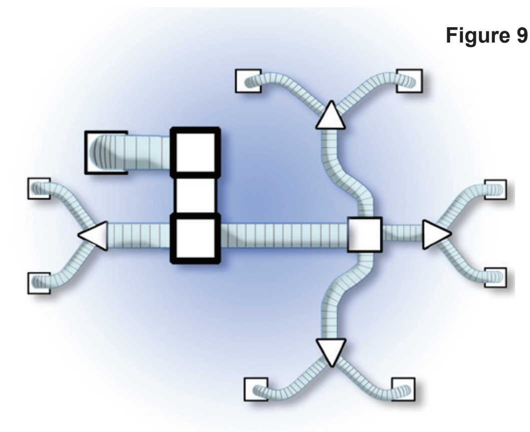


Figure 9

the supply registers. This reduces the number of connections at the supply plenum, lessens static pressure losses and reduces the amount of duct used.

Extended Plenum

The extended plenum duct system (Figure 10) uses a large trunk duct that does not change in size as it travels the entire length of the building. The main trunk duct is considered an extension of the plenum. Accurate design is critical in all systems. Extended plenum systems however, are less forgiving than others and require particularly accurate design. The extended plenum works best if the furnace is in the center of the home.

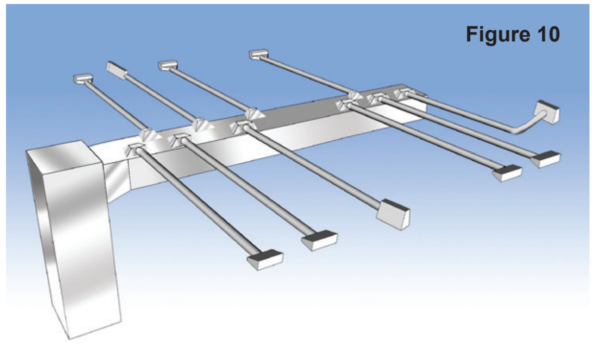


Figure 10

Recommendation for laying out an extended plenum system:

- The supply and return ducts should not extend more than 24 feet from the furnace or air handler
- The first branch should be at least 18 inches from the beginning of the main duct. This helps achieve the best balancing of the branch lines
- The main trunk should extend at least 12 inches past the last branch connection

Reducing Extended Plenum

In a reducing extended plenum or reducing plenum system, (Figure 11) the main trunk line will reduce in size as branch lines are connected. Typically, plenum trunks will reduce

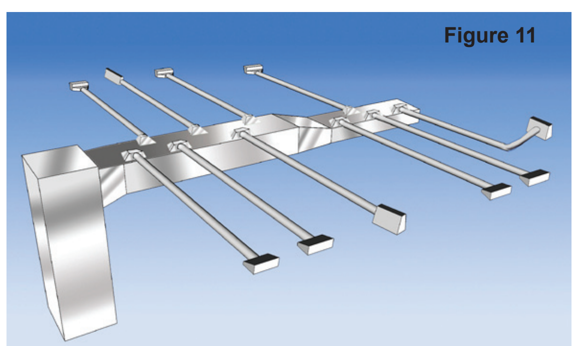


Figure 11

in size after three to four take-offs or every 200-400cfm. A reducing plenum system works well in larger buildings that require longer duct runs.

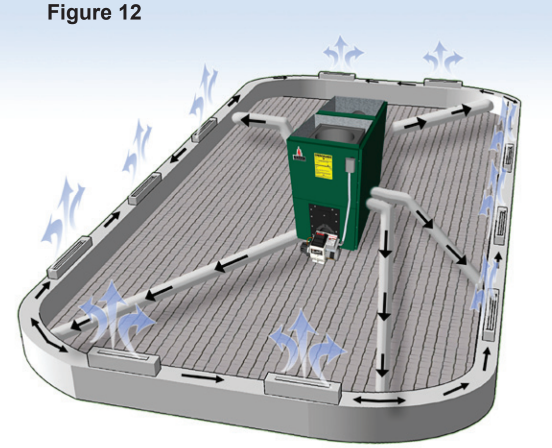
When designed properly, the same pressure drop is maintained from one end of the duct to the other. This allows each branch duct to have about the same pressure pushing air into the takeoff. Recommendations and practices for laying out a reducing plenum duct system are:

- The first main trunk system should be no longer than 20 feet.
- The length of each reducing section should be no longer than 24 feet.
- The first branch connection down from a single side taper should be at least 4 feet from the beginning of the transition fitting. The distance allows air turbulence caused by the fitting to die down before air is sent into the next branch. If the distance is less, the branch line could be hard to balance and noisy.
- The trunk duct should extend at least 12 inches past the last takeoff.

Loop Perimeter Duct System

Loop perimeter duct systems (Figure 12) are common in structures built on concrete slabs. The perimeter loop is a continuous round duct of constant size imbedded in the slab. The duct runs close to the outer walls with outlets located next to the outer wall. The perimeter loop is fed by several branch lines from the plenum. When the furnace blower is running, there is warm air in the entire loop which helps to keep the slab at a more even temperature. Insulation around the slab will reduce heat loss to the outside. The loop has constant pressure throughout the system and provides equal pressure to all outlets.

Figure 12



Duct System Components

Building code requirements for installation of air distribution systems are not uniform and may vary from one location to another. Most localities have minimum standards or codes that determine the types of materials and methods that must be used. Some locations may have requirements for minimum insulation values for ducts in an unconditioned area, as well as for duct sealing and duct testing. Check with the local code authority before starting any work.

The selection and size of trunk and branch lines is based on the air volume (CFM) needed to satisfy the heating and or cooling requirements for the building. A survey of the structure is needed, and then a load calculation must be done to find the heating and or cooling loads. Knowing the heating and or cooling loads, the minimum CFM requirements for a furnace can be calculated by using the following formula:

$$CFM = \frac{Btu/HR}{1.08 \times TD}$$

Btu/HR is from your load calculation

The 1.08 Btu/Hr is the amount of heat needed to raise or lower one cubic foot of water 1 degree at sea level.

TD is the temperature difference or temperature rise.

Assume a building with a heating requirement of 61,000Btu/Hr. By referring to the furnace manufacturer's specifications, choose a furnace that gives a 50º–70ºF rise with a 65,000 Btuh rating. Using a 60ºF rise (which is in the middle of the manufacturer's specifications), the formula looks like this:

$$\text{CFM} = \frac{61{,}000}{1.08 \times 60} \qquad \text{CFM} = \frac{61{,}000}{64.8}$$

$$\text{CFM} = 941.35$$

The duct system would need to have a minimum capacity of 941cfm to meet the heating requirements of the building.

Air ducts can be made from many different materials. The most common are galvanized sheet metal, fiberglass ductboard and flex duct.

Galvanized Sheet Metal

For many years, galvanized sheet metal had been used exclusively. Sheet metal duct can be

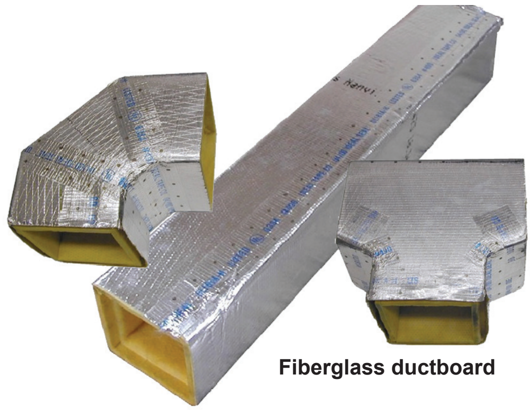
Galvanized Sheet Metal

round, square or rectangular. All three types are often used in a single duct system. Because of its smooth interior surfaces, sheet metal offers the least amount of resistance to airflow of any duct material and sheet metal ducts are also the most durable.

Because of the cost of the material and labor to install sheet metal ducts, other types of materials have become popular.

Fiberglass Ductboard

The inside of surface of fiberglass ductboard is coated with plastic or a similar coating to



Fiberglass ductboard

prevent the release of the duct fibers into the airflow. This creates a rough surface resulting in friction loss greater than found in sheet metal ducts. Fiberglass ductboard is quieter than sheet metal duct because the ductboard absorbs blower and air noises better.

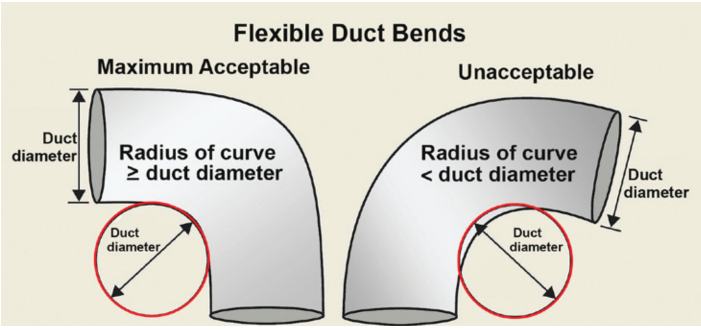
Flex Duct

Flexible round duct comes in sizes up to 24″ in diameter. Flex duct is typically used in spaces where obstructions make rigid duct difficult

Flex Duct

or impossible. Flex duct is popular because it is competitively priced and easy to install. Unfortunately, it is often installed incorrectly.

Common difficulties found with flex duct installation include: tight radius turns, improper support, improperly stretched runs and compressed runs. Flex duct is quiet because its soft sides absorb sound. However, the soft



When making bends or turns with flex duct, the "bend" or "radius" should not be less than one duct diameter.

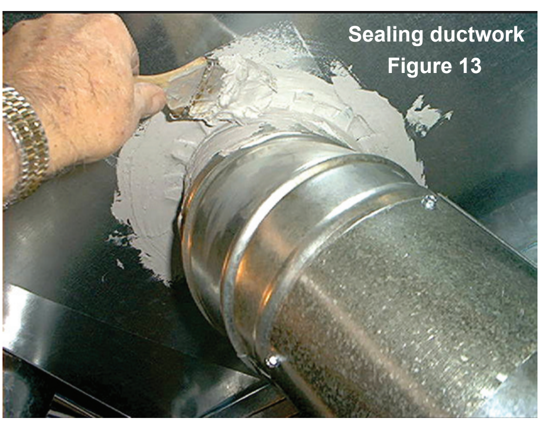
sides also have the highest resistance to air flow compared to the other commonly used materials.

Flex duct runs should be kept short and as straight as possible. Friction losses must be considered on long runs of flexible duct. Even properly installed, flex ducts cause two to four times the friction loss of the same size round duct.

Check with your local jurisdictions prior to installation, since they may have limitations on the length of the runs and required insulation values.

Sealing Ductwork

Unconditioned air leaking into the return air duct can negatively affect system operation and efficiency. The return ducts are under negative pressure, so if they are not sealed (Figure 13, below), they will suck air into any ducts in unconditioned space in the attic or basement.



Sealing ductwork
Figure 13

Conditioned air in the supply ducts is under pressure, and if the ducts are not sealed, it will leak into unconditioned space. This is a waste of energy, and most local codes require the sealing of all seams and connections in metal duct.

Existing ductwork is not always accessible as it may be covered with sheetrock or hidden in a wall. In these cases, there are materials that can seal from the interior of the ducts.

Fiberglass ductboard is sealed with aluminum tape. It is critical to use the tape approved by the ductboard manufacturer and it must be applied according to the manufacturer's instructions.

Flex duct only requires sealing at each connection.

Equivalent Length

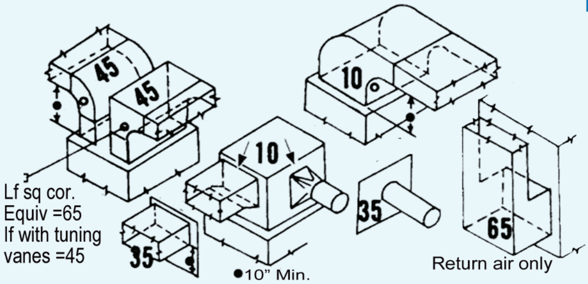
The amount of pressure lost through a duct is directly related to its equivalent length. Every time the air changes direction, pressure is lost. To calculate the pressure loss in an elbow or turn, its equivalent length to straight duct must be known.

The equivalent length of the commonly used fittings can be found on the back of most air duct calculators. (See Figure 14 on following page). A round elbow has an equivalent length of 10′. This means that the elbow is the same as a 10′ length of round pipe. The equivalencies must be taken into consideration when calculating the pressure loss of the system. Use the fittings with the least equivalent length to minimize pressure loss.

Figure 14

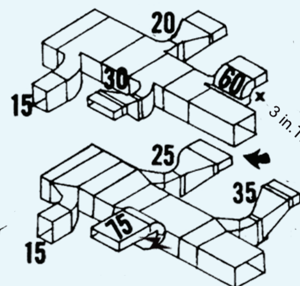
Commonly Used Fitings **Numerals indicate Equivalant Feet of straight duct**

Group 1 Plenums*



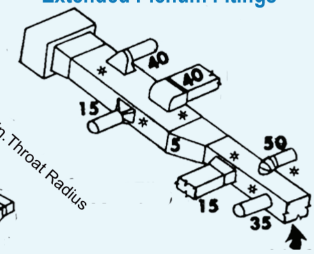
*These fittings may be installed on plenums for counter flow units

Group 2 Plenums
Reducing Trunk Duct Fittings



○Radius No Radius

Group 3 Plenums
Extended Plenum Fitings

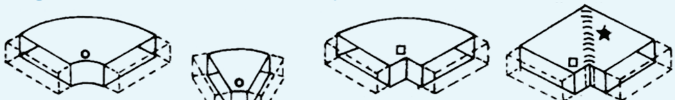


*Add 25 equiv. ft. to ea. of the 3 fittings nearest the unit in each trunk duct and after each reduction as shown by *

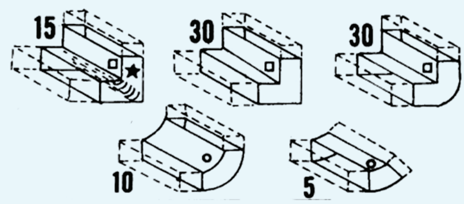
Group 4
Round Trunk Duct Fittings

Group 5
Angles & Elbows for Trunk Ducts (inside Radius =½ Width of Duct)

★Turning vane ☐Square ○Radius

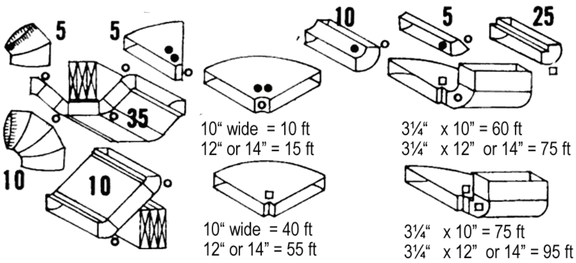


Trunk Width Inches	Trunk Width Inches	Trunk Width Inches	Trunk Width Inches
4"-11"=10 ft	4"-15"=5 ft	4"-6"=20 ft	4"-11"=15 ft
12-21=15 ft	16-27=10 ft	7-11=40 ft	12-21=20 ft
22-27=20 ft	24-41=15 ft	12-15=55 ft	22-27=25 ft
28-33=25.ft	42-47=20 ft	16-21=75 ft	28-42=40 ft
34-42=30 ft	53-64=25 ft	22-27=100 ft	
43-51=40 ft		28-3=125 ft	
52-64=50 ft		34-42=150 ft	

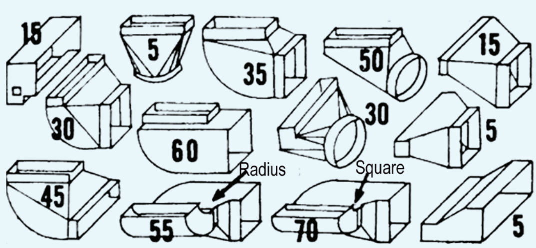


Group 6
Angles & Elbows for Individual and Brach Ducts

○Radius ☐Square Inside Radius ●=3" ●●=5"



Group 7
These values may also be used for floor difuser boxes



Total Eff. Lgth., Duct & Ftgs., in Ft.	Corrected Pressure Drop (Friction) Per 100 FT. Duct Length*																	
	Total Pressure Drop (in. of water column)																	
	.05	.06	.08	.10	.125	14	.16	.18	.20	.25	.30	.34	.375	.40	.50	.625	.75	1.00
35-44	.13	.15	.20	.25	.32	.35	.40	.45	.50	.63	.75	.85	.95	1.00	1.25	1.58	1.90	2.54
45-54	.10	.12	.16	.20	.25	.28	.32	.36	.40	.50	.60	.68	.76	.80	1.00	1.26	1.52	2.02
55-64	.08	.10	.13	.17	.21	.23	.27	.30	.33	.42	.50	.57	.63	.67	.83	1.05	1.26	1.68
66-74	.07	.09	.11	.14	.08	.20	.23	.26	.29	.36	.43	.49	.54	.57	.72	.90	1.08	1.44
75-84	.06	.08	.10	.13	.16	.18	.20	.23	.25	.31	.38	.43	.47	.50	.63	.79	.94	1.26
58-94	.06	.07	.09	.11	.14	.16	.18	.20	.22	.28	.33	.38	.42	.45	.56	.70	.84	1.12
95-104	.05	.06	.08	1.0	.13	.14	.16	.18	.20	.25	.30	.33	.38	.40	.50	.63	.75	1.01
105-114	.05	.05	.07	.09	.11	13	.15	.16	.18	.23	.28	.34	.31	.37	.46	.57	.69	.91
115-129	.04	.05	.07	.08	.10	.12	.13	.15	.17	.21	.25	.27	31	.33	.47	.51	.62	.82
130-149	.04	.04	.06	.07	.09	.10	.11	.13	.14	18.	.21	.24	.27	.29	.36	.45	.54	.72
150-169	.03	.04	.05	.06	.08	.09	.10	.11	.13	.16	.19	.21	.24	.25	.31	.39	.47	.53
170-189	.03	.03	.04	.06	.07	.08	.09	.10	.11	.14	.17	.19	.21	.22	.28	.35	.42	.56
190-214	.03	.03	.04	.05	.06	.07	.08	.09	.10	.13	.15	.17	.19	.20	.25	.31	.37	.50
215-239	.02	.03	.04	.05	.05	.06	.07	.08	.09	.11	.13	.15	.17	.18	.22	.28	.33	.44
240-264	.02	.02	.03	.04	.05	.06	.06	.07	.08	.10	.12	.14	.15	.16	.20	.25	.30	.40
265-289	.02	.02	.03	.04	.04	.05	.06	.07	.07	.09	.11	.12	.14	.15	.18	.23	.27	.36
290-324	.02	.02	.03	.03	.04	.05	.05	.06	.07	.08	.10	.11	.12	.13	.17	.20	.24	.33
325-374	.02	.02	.02	.03	.04	.04	.05	.05	.06	.07	.09	.10	.11	.11	.14	.18	.21	.29
375-424	.01	.02	.02	.03	.03	.04	.04	.05	.05	.06	.08	.09	.09	.10	.13	.16	.19	.28
425-474	.01	.01	.02	.03	.03	.03	.04	.04	.05	.06	.07	.08	.08	.09	.11	.14	.17	.22
475-524	.01	.01	.02	.02	.03	.03	.03	.04	.04	.05	.06	.07	.08	.08	.10	.13	.15	.20
525-574	.01	.01	.02	.02	.02	.03.	.03	.03	.04	.05	.06	.07	.07	.07	.09	.11	.14	.18
575-625	.01	.01	.01	.02	.02	.02	.03	.03	.03	.04	.05	.06	.06	.07	.08	.10	.13	.17

To find the duct system's total equivalent length, add the trunk duct measured length, the branch duct length and the equivalent length of the fittings used from the furnace to the register. Figure 14.

Duct Design Goals

There are three basic goals when designing a duct system. In order of importance they are:

1. Allowing the system to circulate enough air to operate properly. All heating and cooling equipment has a minimum requirement for airflow. A duct system that will not allow the unit to deliver this minimum airflow will cause inefficient operation and potentially shortened equipment life.

2. Distributing the air proportionally to where the load is. To design a duct system that will move an adequate amount of air, the designer needs to know:
    - System CFM
    - Minimum available system static
    - Duct friction rate

3. Keeping airflow noise below objectionable levels.

System Airflow

Airflow is measured in cubic feet per minute or CFM. Systems can operate correctly over a wide range of airflows. The proper airflow requirement can be found in the manufacturer's design and specification literature. If you do not have the manufacturer's specification sheet to work from, use 400cfm per ton for air conditioning or use the following formula for an oil furnace:

$$\text{CFM} = \frac{\text{output Btuh}}{1.08 \times \text{TD}}$$

All duct systems should be designed to the higher airflow requirement, be it heating or cooling. The cooling air requirement is commonly used because the cooling airflow requirement is usually higher than the heating requirement.

Air conditioning or cooling is designed to both lower the temperature of the home and reduce humidity. The airflow over the coil has an impact on the amount of sensible cooling (temperature reduction) versus the amount of latent cooling (humidity removal).

Reducing the airflow increases the amount of humidity removal and decreases the sensible cooling. The amount of sensible and latent loads can be determined by using the Air Conditioning Contractors Association's Manual J. It is important to remember that duct sizing is calculated on the basis of sensible cooling, not total cooling. With the sensible load known, the following formula may be used to find the airflow requirements:

$$\text{Cooling Factor (CF)} = \frac{\text{building cooling CFM}}{\text{sensible heat gain}}$$

This cooling factor would be used to multiply the room Btu requirement to determine the airflow requirements for the area.

On the heating side, we can use the same type of formula to determine our airflow requirements for heating:

$$\text{Heating Factor (HF)} = \frac{\text{building heat CFM}}{\text{sensible heat loss}}$$

The heating factor would be used to determine the CFM requirements for heating each area by multiplying the room Btu requirements.

Maximum Available System Static Pressure

The maximum static pressure the equipment can operate against is specified by the equipment manufacturer. Everything the air must travel through or over will create some static pressure. Static pressure drops will be caused by evaporator coils, humidifiers, air filters, grilles and registers. The amount of pressure drop across any of these devices is directly related to the amount of air going through that device. Increased airflow creates an increase in static pressure loss. The available static pressure is determined by subtracting all the losses from the operating static pressure. Most equipment is designed to operate at peak airflow and efficiency at .5 to .6 static pressure.

Limiting Air Noise

The velocity of the air as it travels through the ducts must be considered as high velocities may cause objectionable noise levels. It is possible to select a duct size that will maintain a workable static pressure with a velocity that creates acceptable levels of noise. To minimize noise, most residential systems are sized in the 600-900fpm range as more than 900fpm almost always causes excessive noise.

Air Distribution System Measurement

Airflow measurements measure the velocity and volume of air as it travels through the system.

Feet per minute (FPM) is a measurement of how fast the air is traveling.

Cubic feet per minute (CFM) is a measurement of the volume of airflow.

Having the correct air volume CFM is critical to any forced air system. Three common instruments are used to measure the static pressure, total pressure and air velocity in an air distribution system:

- Manometers
- Differential pressure gauges
- Pitot tubes, and static pressure tips

Manometers

Manometers are used to measure the low-level static, velocity and total air pressures found in an air distribution system. Manometers used for air distribution systems are calibrated in inches of water column (in. w.c.). Manometers can use water or oil which has a specific gravity of 0.826 as the measuring fluid. The manufacturer specifies the type of oil to be used. Manometers come in many types, including U-tube, inclined and combined U-inclined. Electronic manometers are also widely used. Pitot tubes or static pressure tips are always used with manometer.

Individual U-tube and inclined manometers are available in many pressure ranges. Inclined manometers are usually calibrated in the lower pressure ranges and are more sensitive than U-tube manometers. U-inclined manometers combine both the sensitivity of the inclined manometer with the high range capability of the U-tube manometer in one instrument.

Inclined vertical manometers combine an inclined section for high accuracy and a vertical manometer section for extended range. They also have an additional section that indicates air velocity in feet per minute (fpm). Electronic manometers typically measure differential pressures in inches of water column (in w.c.).

Differential pressure gauge

These provide a direct reading of pressure. These gauges are typically used to measure fan and blower pressures, filter resistance, and air velocity and furnace draft. Some are capable of measuring just pressure or both pressure and air velocity.

Pitot tube and the static pressure tips

These are probes used with manometers and pressure gauges for taking measurements inside duct work. Pitot tubes come in various lengths ranging from 6" to 60".

Static pressure tips, like pitot tubes, are used with manometers and differential pressure gauges to measure static pressure in a duct system. They are typically L-shaped with four radial drilled 0.04" sensing holes.

Inclined manometers and pitot tubes measure the pressure in a duct. They cannot be used to measure airflow at a register or grille.

Instruments are available that read FPM, CFM or both directly, without having to read the pressure in the duct. Some direct reading airflow instruments used are the rotating vane anemometer, the thermal anemometer and the flow hood.

Air Velocity Measurement Instruments

Velometer—Measures the velocity of airflow. Most velometers give direct readings of air velocity in fpm. Some can even provide direct reading in cfm.

Rotating vane anemometer—Consists of a lightweight, air-propelled wheel, geared to dials that record the feet of air passing through the instrument. Anemometers read feet of air per minute (FPM) or cubic feet per minute (CFM). The rotating vane anemometer is placed in the airstream and readings are taken for a measured amount of time.

Thermal Anemometer—Operates on the principle that the resistance of a heated wire will change with its temperature. The probe is placed in the airstream and the velocity is indicated.

Flow hood—Accurately determines the airflow volume in CFM from an outlet by collecting the air supply, directing it through a one foot square opening where a calibrated manometer provides the CFM readout. Flow hoods are considered the most accurate measurement of airflow through registers and grilles.

Figure 15

For PSC systems, the 1/2 hp motor is equipped with 4 speeds.
The unit is set for the mid-fire temp rise @ 66°F. See table for poper blowe motor setup.

Alterations Required for A/C @ Design External Static Pressure				
Cooling Unit	Heating Speed by Input			Recommended CLG Speed
	Low Fire	Mid Fire	High Fire	
24,000	Low	ML	MH	Low
30,000	Low	ML	MH	Med Low
36,000	Low	ML	MH	Med High
42,000	Low	ML	MH	Med High
48,000	Low	ML	MH	High

Furnace Airflow - CFM vs. External Static Pressure (in W.C.)							
Speed Tap/ Static Pressure	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Low	930	915	912	910	822	774	730
ML	1155	1152	1130	1126	1085	1042	920
MH	1442	1432	1418	1382	1334	1293	1230
High	1802	1762	1705	1635	1569	1493	1428

Furnace Motor Current Draw (Amps) vs. External Static Pressure (in W.C.)							
Low	3.3	3.1	3.0	2.9	2.6	2.5	2.4
ML	4.2	4.0	3.9	3.7	3.6	3.3	3.0
MH	5.4	5.2	5.0	4.7	4.4	4.2	4.0
High	6.6	6.4	6.0	5.7	5.5	5.2	5.0

High Fire Temperature Rise vs. External Static Pressure (in W.C.)							
Speed Tap/ Static Pressure	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Low	90	91	91	92	101	108	114
ML	72	72	74	74	77	80	91
MH	58	58	59	60	62	64	68
High	46	47	49	51	53	56	58

Mid Fire Temperature Rise vs. External Static Pressure (in W.C.)							
Speed Tap/ Static Pressure	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Low	72	73	73	73	81	86	91
ML	58	58	59	59	61	64	72
MH	46	47	47	48	50	52	54
High	37	38	39	41	42	45	47

Low Fire Temperature Rise vs. External Static Pressure (in W.C.)							
Speed Tap/ Static Pressure	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Low	60	61	61	61	68	72	76
ML	48	48	49	49	51	53	60
MH	39	39	39	40	42	43	45
High	31	32	33	34	35	37	39

Troubleshooting airflow problems

A Department of Energy report, http://www.nrel.gov/docs/fy05osti/30506.pdf, has indicated that ducts may have efficiencies of 60-70%. This significantly decreases the overall efficiency of the system. A system with an 85% efficient furnace and a duct efficiency of 60% will deliver a little over 55% overall efficiency to the building (.85 x .65 = 55.25%) .

When measuring airflow, it should be checked and verified. For example, if we check airflow by performing a Total External Static Pressure test, we could verify by checking the temperature rise or amperage draw. This chart (Figure 15) shows the correlation between airflow, static pressure and temperature rise for a specific furnace.

Temperature Rise Measurements

Temperature rise can also be used to verify the measurements of pressure that have been performed. To do a temperature rise assessment, find the furnace output ratings from the equipment rating plate if available. If not, you can determine the Btu output by checking the nozzle size and fuel pump pressure to determine the Btu input. Then do a combustion efficiency test to find output Btu and use the following formula:

$$\frac{\text{Btu Input x Combustion Efficiency}}{\text{1.08 x Temperature Rise}} = \text{CFM}$$

For Example

- A furnace with 105,000 Btu input
- 85% combustion efficiency
- 75 degree temperature rise

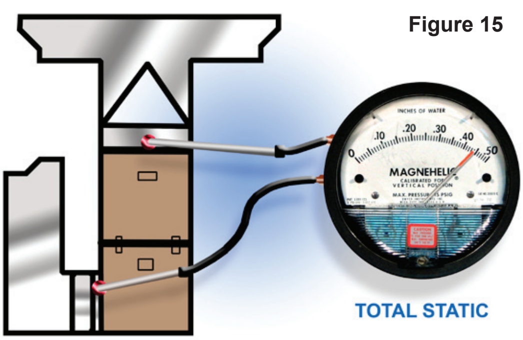
$$\frac{105{,}000 \text{ x } .85}{1.08 \text{ x } .75} \quad \frac{89{,}250}{81} = 1{,}102 \text{ CFM}$$

Many manufacturers have done these calculations and they are usually in the installation instructions.

Using Static Pressure Drop to Measure System Airflow

The volume of air moved by a blower is dependent upon the pressure that the blower is working against. The airflow can be accurately determined by measuring the pressure drop across the blower or any component in the airflow and using the manufacturer's specifications. To determine the amount of air a blower is moving:

Figure 15



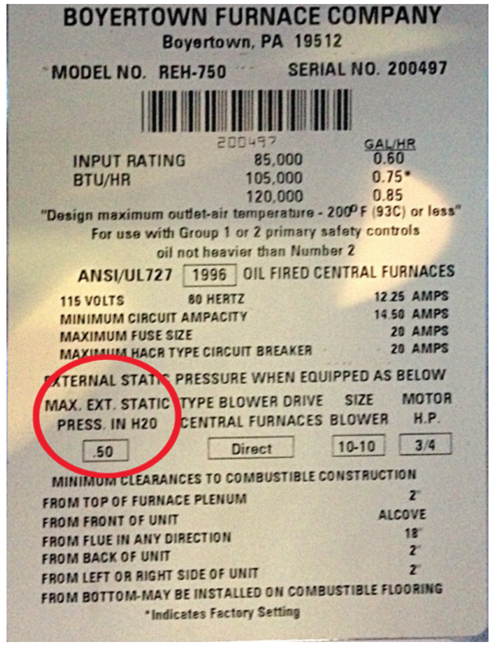


Figure 16

1. Measure the total static pressure difference across the blower, filter, or evaporator coil (Figure 15).

2. Compare the static pressure difference to the manufacturer's specifications to determine the system airflow. Static pressure charts are model specific.

Most equipment is rated to give the best performance and maximum airflow at around .50 to .60 static pressure. This information can be found on most equipment manufacturers' labels (Figure 16, above).

Measuring Airflow at Registers and Grilles

The easiest and most accurate method for measuring the airflow at registers and grilles is with a flow hood. The flow hood is placed over the register or grille, forcing all the air passing through the register or grille on to the flow hood. The CFM is read directly on the flow hood.

Airflow at registers and grilles can also be calculated with anemometers or velometers by measuring the average airflow velocity and multiplying it by the free area of the register or grille. The free area of a grille can be found in the manufacturer's literature. If the manufacturer's information is not available, a good "rule of thumb" is to estimate the free area as approximately 60% of the overall grille. For example, a 10" x 6" grille provides 42 sq. in. of free area.


Figure 17

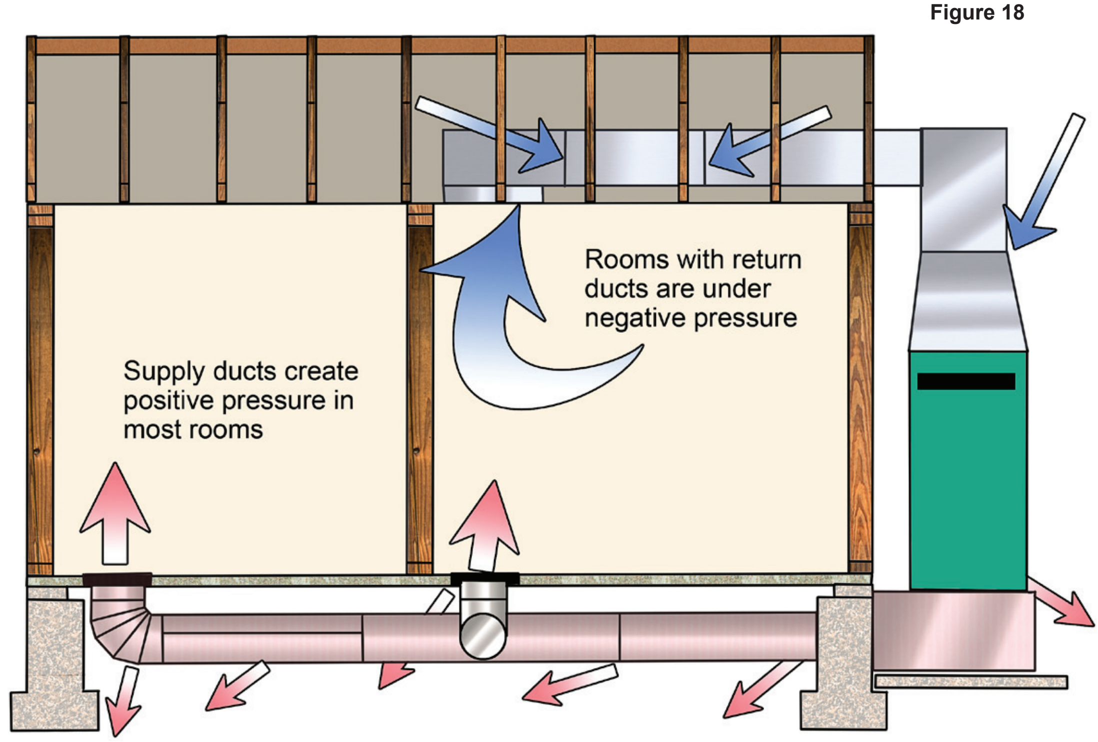
Duct Leakage Testing

Increasingly, local codes are requiring duct leakage testing at the time of a new complete system installation (Figure 17). Leaks in ducts can add to the operating cost of any heating or cooling system. For example, drawing in cold air from an attic, which is then subsequently heated by the furnace, will reduce the temperature rise and require the furnace to run longer. (Figure 18). Leaks in the supply ducts will reduce the heated air delivered to the living place. Reducing duct leakage therefore increases total system efficiency.

Prior to testing, the system should be started to confirm airflow at the return and that the system is supplying air to all registers. Once these preliminary checks are made, the duct leak test can be done.

Duct leakage is determined by blocking all duct outlets, pressurizing the duct and measuring the amount of air that is required to maintain that pressure. As air leaks out of the

Figure 18



supply ducts, replacement air is drawn into the return ducts and register. In a system with no leaks, no additional airflow should be required to maintain the pressure once the duct has been pressurized.

There are several ways to conduct a leak test. The standard method is the use of an orifice tube. The orifice is certified and designed for a specified flow curve. A pressure source is installed to pressurize the duct system. Typically, an axial fan (duct blaster) with an inlet damper to control airflow and limit pressure to the duct system is used. Two manometers are used, one installed to measure pressure drop across the orifice and the other to measure static pressure in the ductwork at the farthest point from the orifice.

The pressure supplied to the system should not exceed the maximum design ratings that are specified for the system. The technician should read the pressure drop across the orifice and then compute the flow rate using the flow curve data. The actual leakage rate can then be compared with the allowable leakage rate of the duct system. Most systems should have a loss rate no greater than 2%. Check local codes to determine the acceptable leakage rate in that jurisdiction.

Once the inspection and leak test are completed, a report should document the test for future reference. If the duct system is out of design tolerance, the system should be corrected to meet design conditions before attempting to balance the system.

System Startup and Air Balancing

When starting up a new system, design setup information including unit specifications, control systems details, job layout and airflow quantities for each register and grille should be included in a commissioning report for future reference. The report may also be useful in assessing warranty claims.

After gathering all the system data, the overall system airflow should be measured and compared to the required airflow in the design specification. The actual airflow must not vary more that 5% from the required airflow. Until the actual overall airflow is correct, there is no reason to evaluate airflow at the registers.

The next step is to use a flow hood, velometer, or anemometer to measure the airflow at each supply register and return grille. The sum of all CFM measurements should be within 10% of the system CFM at the blower. Leaks in the return duct system will cause the air entering the return air grilles to be less than the total amount of air the blower is moving. If the difference is more than 10%, the leaks in the return duct must be sealed.

Similarly, the total of all the CFM measurements at the individual supply registers should be within 10% of the system CFM at the blower. Leaks in the supply duct system will cause the air leaving the supply registers to be less than the total amount of air the blower is moving.

Once the total delivered airflow is within tolerances, the supply register measurements should be compared to the design specifications for each area. Dampers can now be adjusted to achieve the correct airflow for each register. Start with all dampers open, then partially close the dampers to the registers that are delivering too much air. Begin with the registers that exceed design specifications by the biggest margin.

Measurements should be taken after each adjustment to determine the effect of the adjustment on the other registers in the system.

Testing Heat Exchangers For Leakage

Heat exchangers separate combustion gases from the heated air that the blower distributes throughout a building. If a leak develops in a heat exchanger, carbon monoxide (CO) can enter into the heated air and pose a health and safety risk to the building's occupants.

There are a number of indications that a heat exchanger may be leaking, including:

- A flame pattern change when the blower comes on;
- A properly located CO alarm sounding;
- Odors and/or soot in the home.

There are numerous ways to test for heat exchanger leakage; among the most effective are:

1–A visual inspection

2–Measuring the CO in the return air and in the supply air. If the CO reading in the supply is higher than in the return, the heat exchanger may be defective and a through visual examination is required to search for cracks or other problems.

3–Measuring the steady state O2/CO reading at the breach before and after the blower comes on. If the O2 reading changes, or the CO reading increases by more than 10%, the heat exchanger may be defective.

4–An over-fire draft test. Measure the over-fire draft while the burner is operating at steady state and the blower is off. Then energize the blower. If the draft changes, the heat exchanger may be defective and a thorough visual examination is required to search for cracks or other problems.

Note: When using instruments to test for a defective heat exchanger, make sure that cleanout ports and gaskets are fully secured, all furnace access panels for air distribution are in place and that there is no leakage on the return side of the furnace.

Ventilation

Ventilation is necessary for maintaining acceptable indoor air quality and to minimize adverse health effects. Improved construction techniques continue to tighten new and existing homes requiring us to focus on indoor air quality.

Tightening a house, eliminating leaks in the building envelope will reduce the number of times the building air changes. This will save energy and improve comfort by eliminating drafts. Proper sizing and controlling of the ventilation system is crucial for ensuring pollutants do not enter the occupied space and maintaining the right level of humidity.

A home can quickly become depressurized from the operation of a clothes dryer, central vacuum, kitchen and bathroom exhaust without proper ventilation and makeup air.

When a house is depressurized, air is pulled into the home through the heating chimney and the unhealthy air can enter through the garage, attic or crawl space. Soil gas can enter through cracks in the foundation or around the sump area. Air can also be pulled down interior and exterior walls and exits around electrical outlets bringing with it what was in the wall cavity. The best solution is to use a well-designed ventilation system that can deliver fresh air all year long, even when not heating or cooling.

This type of an approach allows a strategy for managing moisture and indoor pollutants while still delivering comfort and efficiency to the occupants.

The American National Standards Institute (ANSI) and the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) have developed minimum standards for ventilation: *ANSI /ASHRAE 62.1 Ventilation and Acceptable Indoor Air Quality.*

A standard for all spaces intended for human occupancy except those within single family houses, multifamily structures of three stories or fewer above grade, vehicle and aircraft.

ANSI / ASHRAE 62.2 Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings (three stories or less)

These ventilation standards are available for purchase from ASHRAE. (www.ashrae.org); phone 404-463-8400; 1791 Tullie Circle NE. Atlanta GA 30329.

There are three basic ventilation types:

Supply Ventilation

- Uses a fan to force outside air into a home
- Can operate continuously or intermittently and be ducted to single or multiple locations
- A Central Fan Integrated Ventilation system differs because it uses a control and inter faces with the HVAC system central fan for whole house ventilation.

Exhaust Ventilation

- Uses a dedicated fan or bath fan to exhaust air from the home
- Replacement air is uncontrolled and ventilation is typically distributed unevenly
- Pockets of poorly ventilated areas can exist

Balanced Ventilation

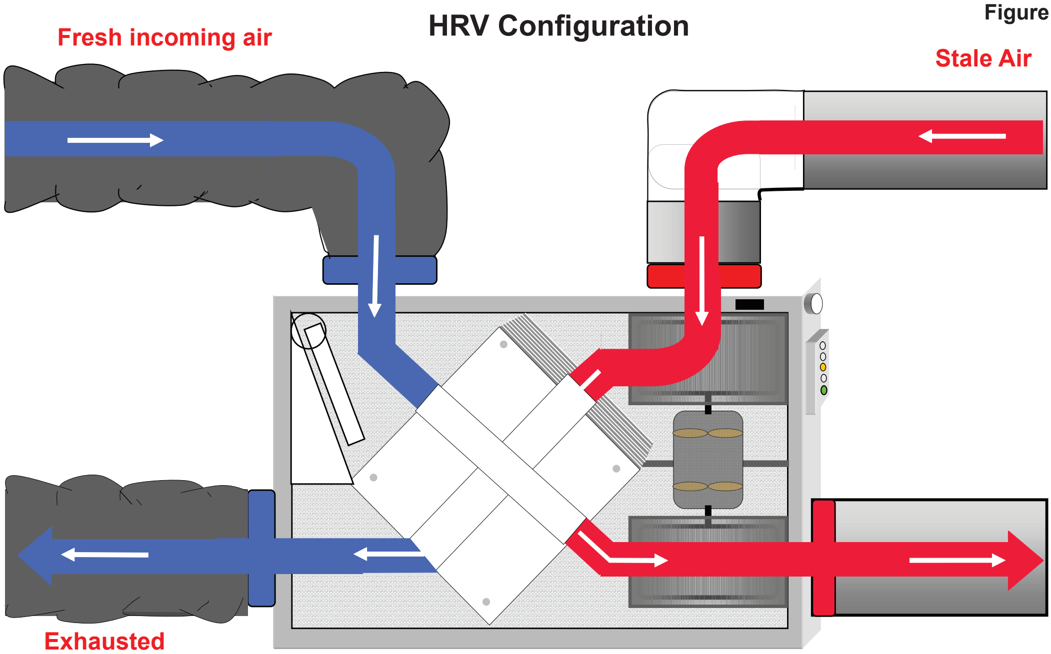
- Uses a fan to bring air into the home while simultaneously exhausting an equal amount of air from the home.
- The system can operate continuously or intermittently—Heat Recovery Ventilator (HRV), Figure 19 or Energy Recovery Ventilator (ERV), respectively
- The system can be connected with the centrally ducted system for whole house ventilation or can be independently ducted to serve one or more areas.

Heat Recovery Ventilator

Healthy Home System Control Plus (HHSC+)

HRV Configuration

Figure 19



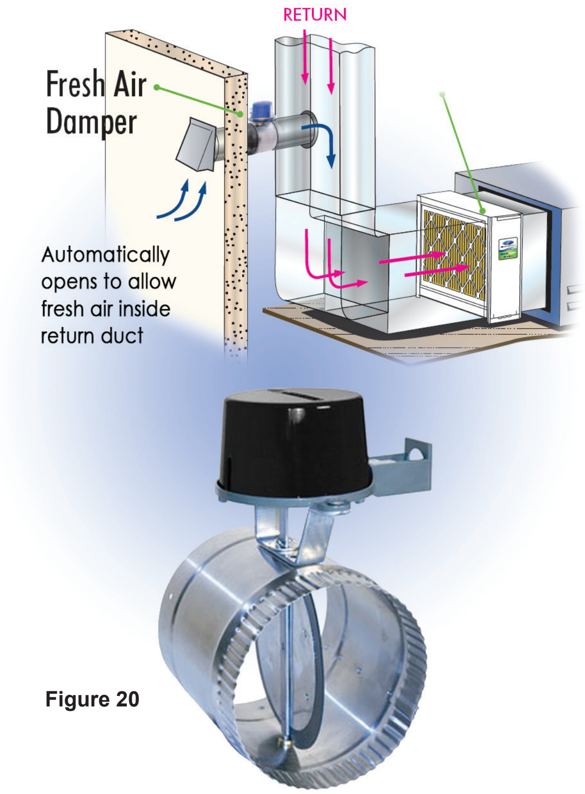


Figure 20

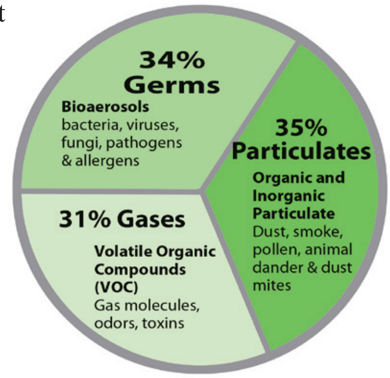
Figure 21

and Fresh Air Damper (Figure 20) can meet the ASHRAE 62.2 residential ventilation standard.

Healthy Home System Control Plus is a multifunctional programmable control, Figure 21. It operates in parallel with a ducted HVAC appliance to minimize electrical cost and deliver fresh air even when not heating or cooling. When utilized with properly sized fresh air dampers, the system can manage ventilation and make up air requirements.

Indoor Air Quality

In 2012, the Environmental Protection Agency declared Indoor Air Quality a National Health Hazard. Indoor Air Quality is among the top five risks to the nation's public health. The Environmental Protection Agency and the Center for Disease Control place indoor Air Quality into three important categories: Germs, Gases and Particulates.



The pie chart helps identify the average percentages of contaminants. As you can see, Germs contribute approximately 34%. They are known as bio-aerosols: bacteria, viruses, fungi, pathogens and allergens.

Gases contribute approximately 31%. These are Volatile Organic Compounds (VOCs) which consist of gas molecules, odors and toxins.

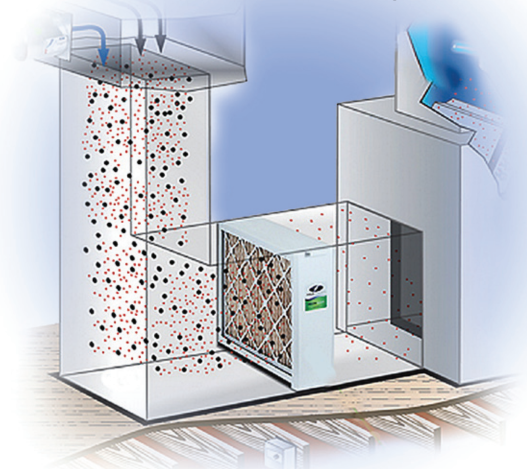
Particulates contribute approximately 35% and consist of organic and inorganic particulates, such as dust, smoke, pollen, animal dander and dust mites.

The first step in improving indoor air quality is to reduce or eliminate the source of pollutants.

Particulates

The typical HVAC ducted system usually has a one-inch filter. The average low cost inefficient filter merely keeps the appliance clean. To make a difference in airborne particulate capture, a MERV-8 to MERV-13 is a sound approach. The higher MERV rating indicates better particulate capture. Static pressure usually increases with a higher MERV rating. A ducted system must be properly designed to handle the increase in static pressure. A poorly designed duct system can negatively impact an appliance's efficiency and life cycle, Figure 22. All systems require regularly scheduled maintenance.

Figure 22



Typical up-flow appliance with particulate capture in the return air duct

Gases

The first step in dealing with gases is to minimize or eliminate the source when possible. Gases can come from building materials, carpet, aerosols, including hair sprays, perfumes, paint, varnishes, polyurethane, sealers, air fresheners, household cleaners, bleach, fuels, unvented combustion appliances, cook stoves and more.

Gases can be managed with a properly designed ventilation system. A system can consist of spot exhaust ventilation when dealing directly with a source, such as the kitchen and bath exhaust.

The best systems manage outside air intake with filtration and a control strategy. Remember, when exhausting air from a structure, replacement air will enter to balance the pressure differential. A good reliable source of managed intake air from outside is highly recommended.

When ventilation is not possible, there are other options, such as carbon filtration and/ or photo catalytic oxidation (PCO). PCO can reduce gases. Figures 24 on next page. The PCO units consist of a titanium dioxide-coated substrate and are illuminated with ultraviolet light. Such systems require adequate surface area to effectively reduce gases, and a small system with very little surface area placed into a residential duct system will have minimal effect.

The Environmental Protection Agency (EPA) doesn't recommend the use of ozone/activated oxygen in the residential occupied space for improving indoor air quality.

Germs

UVGI Ultra-Violet Germicidal Irradiation

Germicidal lamps typically operate at a wavelength between 220 nanometers and 280 nanometers. The band is called UV-C. Some partially operate between 180 nanometers and 220 nanometers. The band is called UV-V. (Ozone producing band).

The use of UVGI C band systems (Figure 23) can prevent microbial growth in drain pans and evaporator coils. Implementing a UVGI system with a dirty coil can allow dry airborne particulate to be distributed into the occupied

Typical residential UVGI Products

Figure 23

space. It's recommended that a dirty coil be cleaned prior to implementing a UVGI system.

To effectively kill germs, a UVGI system must be properly sized.

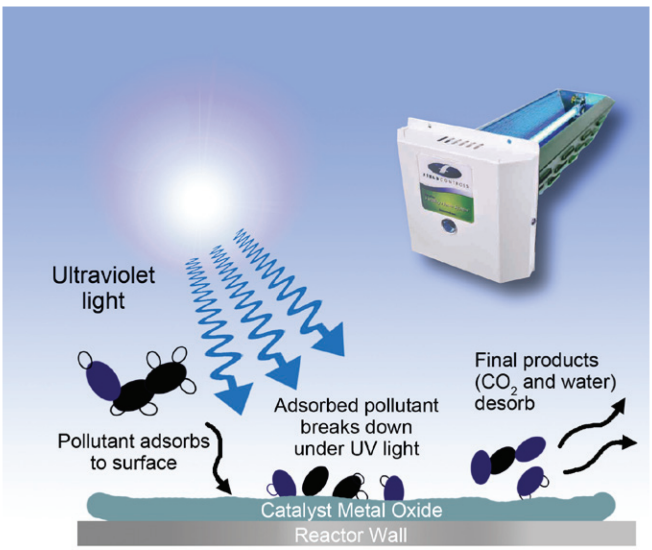
The information below is from the US Environmental Protection Agency about ozone:

- Good up high and bad nearby EPA Publication 451/K-03-001

- Whether pure or mixed with other chemicals, ozone can be harmful to your health!

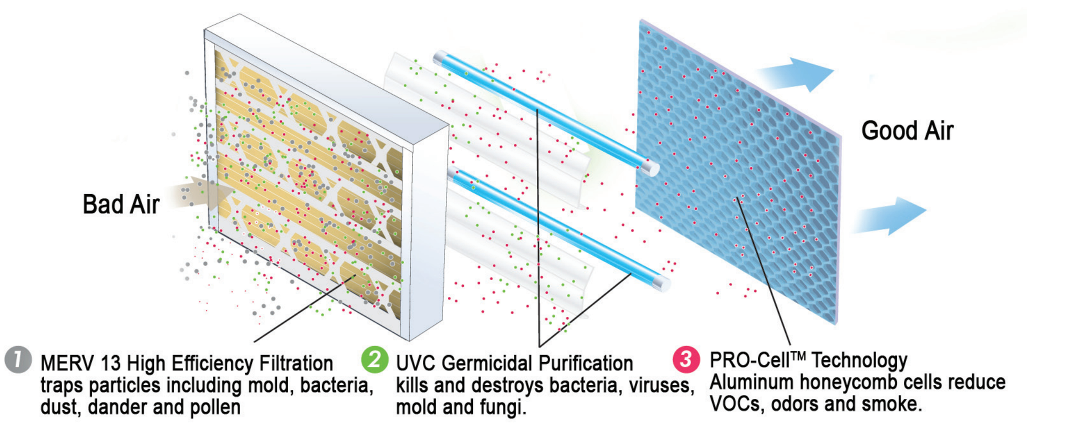
- Available scientific evidence shows that

Figures 24 **Examples of PCO Science/ Photo Catalytic Oxidation Technology**



Duo
50 watts UVC lamp 3500 square inches of Pro Cell catalyst

TRIO
8,065 square inches of catalyst 16 x 25
10,080 square inches of catalyst 20 x 25



at concentrations that do not exceed Public Health Standards, ozone has little potential to remove indoor air contaminants.

• If used at concentrations that do not exceed public health standards, ozone applied to indoor air does not effectively remove viruses, bacteria, mold or other biological pollutants.

Hydro-air applications

Hydro-air installations use an air handler to provide air flow to an indoor coil for cooling and a hydronic coil for heating. A boiler supplies hot water to a coil encased in an air handler; the air handler provides the supply air to distribute through the home. Some of the key features are venting, zoning, boiler versatility and air flow.

With a hydro-air system, venting is only necessary at the boiler. Combustion doesn't take place at the air handler, thus eliminating the need for a heat exchanger, venting, fuel supply, and combustion air for each air handler or zone.

Zoning is accomplished by installing on each system a thermostat, duct system and an outdoor unit. Zone valves at the boiler control the input to the hydronic coil.

The boiler can have many functions besides providing hot water to the hydronic coil. The boiler can heat domestic hot water, provide hot water for a baseboard loop or for a radiant system in the garage or a loop for snow melt.

Air flow can be designed for a particular zone. Hydro-air systems normally run with a lower CFM than a hot air system, allowing lower temperature rises and longer run times. Installing one complete duct system in an existing home can be quite intrusive while hydro systems can consist of a number of small duct systems throughout the home.

Please remember all duct design rules for supply ducts and returns apply to hydro systems as well.

IMPORTANT FORMULAS

$$\text{Fan rpm} = \frac{\text{diameter of motor pulley x motor rpm}}{\text{diameter of fan pulley}}$$

New cfm = (new rpm x existing cfm) divided by existing rpm

New rpm = (new cfm x existing rpm) divided by existing cfm

New s.p. = existing s.p. x (new rpm divided by existing rpm)^2

New hp = existing hp x (new rpm divided by existing rpm)^3

$$\text{CFM} = \frac{\text{BTU/Hr(required)}}{1.08 \text{ X TD}}$$

$$\text{Heating Factor (HF)} = \frac{\text{building heat CFM}}{\text{sensible heat loss}}$$

$$\text{Cooling Factor (CF)} = \frac{\text{building cooling CFM}}{\text{sensible heat gain}}$$

$$\text{Cooling Factor (CF)} = \frac{\text{building cooling CFM}}{\text{sensible heat gain}}$$

$$\text{CFM} = \frac{\text{OUTPUT BTU}}{1.08 \text{ X TD}}$$

CFM = AREA X VELOCITY

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