

AIR FLOW MEASUREMENT

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INTRODUCTION

Poor system performance and reliability is often a direct result of improper air flow. Unfortunately the lack of proper air flow goes unnoticed and is improperly diagnosed in most cases. A true technician in the air conditioning field must not only understand refrigeration and electricity but also possess a knowledge of the properties of air and air measurement.

The intent of this text is to discuss various methods used in the field for air measurement. It is not the intent of this program to explain duct design and layout.

Each method of air measurement has its advantages and disadvantages when applied to any particular application. The technician must be knowledgeable of what method to use in obtaining the most accurate results.

The methods of air measurement that will be discussed are the use of pitot tubes and inclined manometers, total system external static pressure, static pressure drop across indoor coils, rotating and deflecting vane anemometers, hot wire anemometers, temperature rise method and fan curves. Let's begin by first discussing duct system pressures.

DUCT SYSTEM PRESSURES

The pressures in a duct system produced by a fan are small and therefore difficult to measure. The measuring scale must be large in order to accurately read this pressure. Atmosphere pressure is the equivalent of 14.696 pounds per square inch absolute and lifts a column of mercury 29.92 inches. These two scales are not accurate enough to measure the pressure in a typical duct system. Atmospheric pressure will also maintain a column of water 33.9 feet or 406.8 inches. Because the inches of water column scale is numerically large it will be more accurate to use than the other scales mentioned. One pound per square inch of absolute pressure is the equivalent of 27.68 inches of water column pressure. (Figure 1)

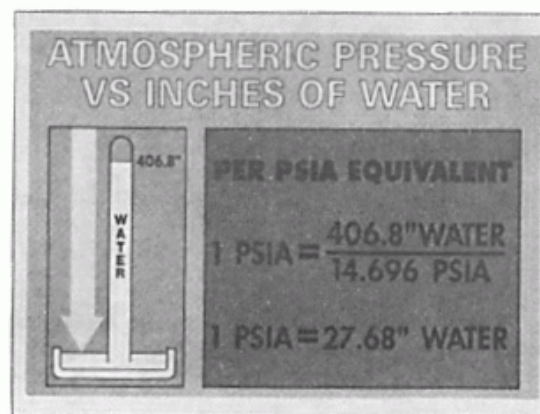


Figure 1

To measure inches of water column pressure an inclined manometer, u-tube manometer, or a magnehelic may be used. (Figure 2)

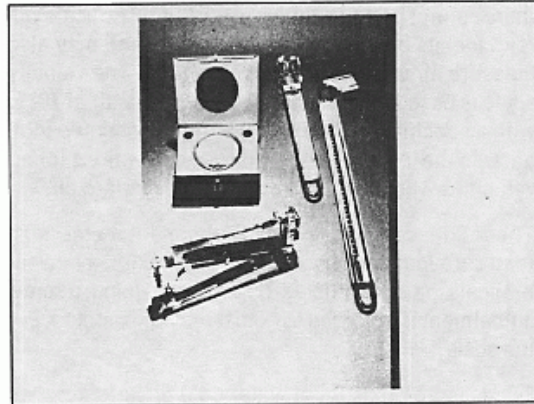


Figure 2

INCLINED MANOMETERS

Let's discuss the inclined manometer first. There are several ranges available for this instrument. The smaller the range, the more accurate the readings. The manometer uses an oil specifically designed and calibrated for use with the instrument. It typically has a specific gravity of .826 and substitution for this oil is not recommended. (Figure 3)

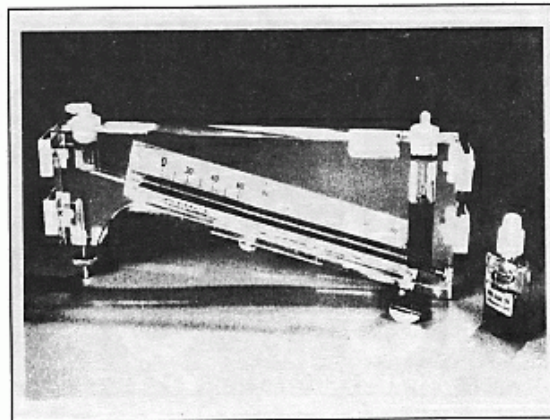


Figure 3

To use the manometer, attach it to a location convenient to the area of the duct where the pressure readings are to be taken. Magnets are provided on some of the manometers, while others may require screw connection. The gauge must be installed level. This can be easily checked by the spirit level on the instrument. The two pressure connection ports must be open and the fluid must have freedom of movement. When opening these ports tilt the manometer back and forth to check for fluid movement. Do not open these ports too far, as a leak for the pressures to be measured may result in erroneous readings. The ports should be closed when the device is not used to prevent fluid loss.

The manometer must be free of dirt, scale buildup and there cannot be any bubbles in the fluid. The scale will read inches of water column pressure and may also measure air velocity in feet per minute. The velocity scale is based on standard air. This is dry air at 70° F, with a specific density of .075 pounds per

cubic foot. Later in the lesson, we will discuss corrections for air velocities when the air is other than standard air.

The fluid level or meniscus in the manometer must read zero inches of pressure. If it does not, a moveable scale may be adjusted. If the scale is fixed, a screw adjustment is provided to adjust the fluid meniscus to the scale.

To measure pressure of water columns greater than the range of a typical inclined manometer, a u-tube manometer is used. The u-tube manometer may also use a fluid with a certain specific gravity such as .826 which is stamped on the scale face. Some u-tube manometers use water and therefore measure one inch of length for each one inch of pressure.

The manometer is installed vertically and zeroed. After the gauge has been zeroed and the pressure applied, both fluid columns will deflect in opposite directions from the zero point on the scale. The total pressure applied to the gauge is the sum of each column height from zero. In the example of Figure 4, the manometer on the left has been zeroed. At the right, pressure is applied to one side of the fluid column. The total pressure applied would be the sum of each column's distance from zero. In this example, 2 plus 2 equals 4 inches of water column pressure that has been exerted.

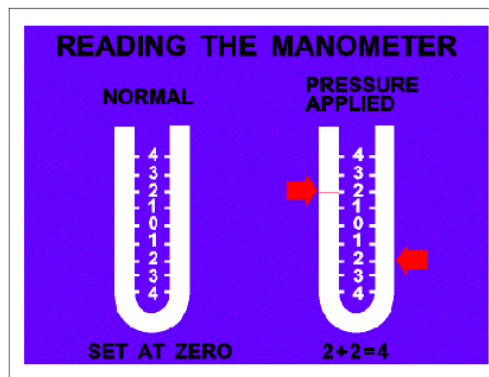


Figure 4

If the gauge has not been zeroed because of an excess or shortage of fluid, it may still be used. In Figure 5, the manometer on the left has no pressure applied and is not zeroed. Pressure has been applied to the manometer on the right. The total pressure is still the sum of the total distance of each fluid column from zero. In this example the pressure is equal to 1.5 plus 2.5 inches or a total of 4 inches of water column pressure.

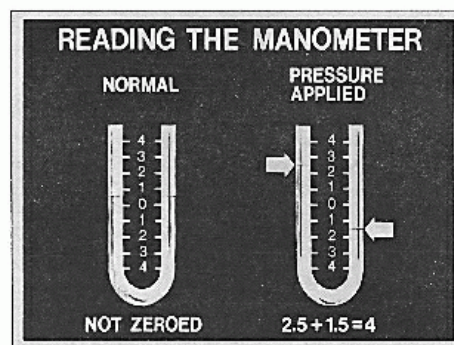


Figure 5

Some manometers combine the sensitivity and accuracy of the inclined scale with the higher pressure range of the u-tube manometer. The manometer has two scales with each having its own zero point.

As shown in Figure 6, the scale on the left is used to read lower pressure readings and the manometer is tilted, zeroed and read directly as an inclined.

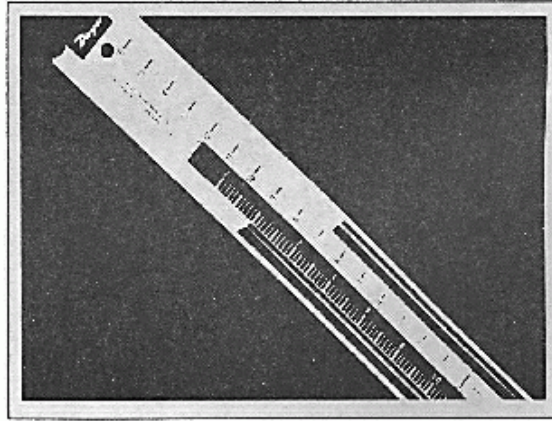


Figure 6

In Figure 7, the manometer is used to read higher pressure by mounting it vertically, zeroing the fluid level and reading the scale on the right.

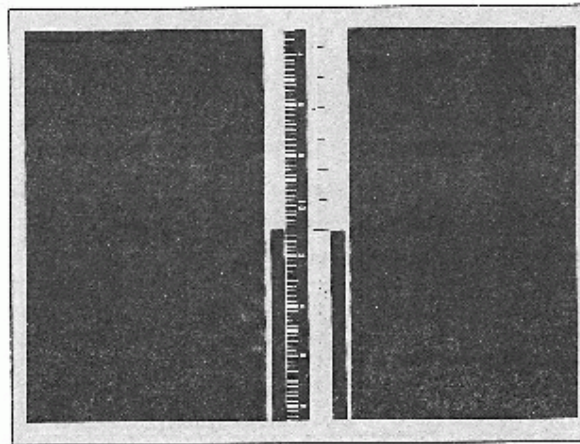


Figure 7

Other instruments used in air measurement that read inches of water column pressure without using fluid levels are called magnehelics as shown in Figure 8.

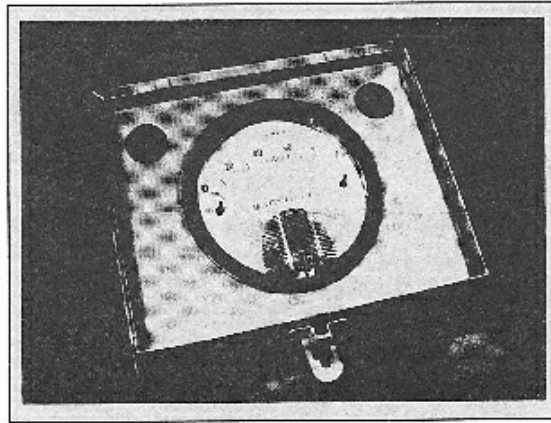


Figure 8

Next, let's discuss the duct system and see how the manometer is used to read duct pressures.

MEASURING DUCT PRESSURES

To explain duct pressures, let's use a forward curved centrifugal fan and a section of duct work containing a 100% shut-off damper. If the fan is operating and the damper is closed, the fan will pump air into the duct work and as a result of the air being compressed, the duct pressure will increase. The pressure in the duct work is attempting to expand the duct and cause it to bulge as in Figure 9. This pressure is known as static pressure. Static pressure is defined as a pressure at rest, it possesses potential energy and the ability to do work. The direction of the lines of force of static pressure are exerted in all directions. It is the same force as air pressure in a balloon or tire. Like the balloon, static pressure in a duct causes no movement of air. When air does move, it moves from areas of higher to lower static pressures. The total duct pressure in this example with the damper closed, is equal to static pressure.

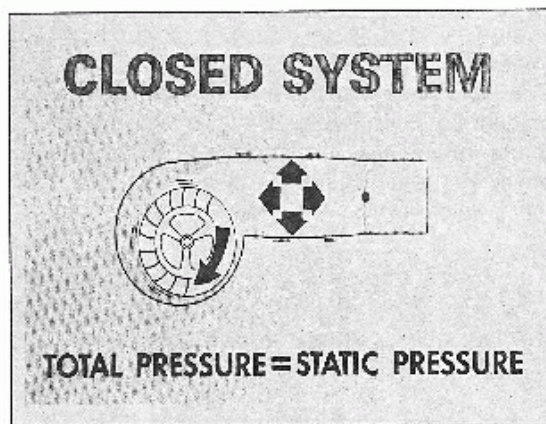


Figure 9

If the damper is partially open, see Figure 10, the static pressure or potential energy in the air is converted to kinetic energy. Kinetic energy is energy in motion. This air movement through the duct can be felt and is called velocity pressure. The same thing happens when an expanded balloon is let loose. The static pressure converts to velocity pressure and propels the balloon through the air.

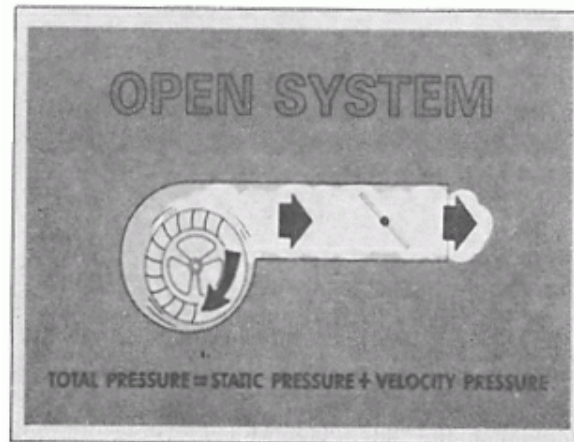


Figure 10

Velocity pressure has its lines of force in one direction, which is always toward the path of least restriction or in the direction of the air flow. Velocity pressure is the force that closes a sail switch to sense air flow movement or turn a child's pinwheel. The total pressure in the duct system with the damper partially open equals the sum of the static pressure plus the velocity pressure.

To measure static pressure in the duct system, connect a manometer as shown in Figure 11 on the left side. We are using a u-tube manometer in this example. To measure total pressure in the duct, the manometer is connected as shown on the right of Figure 11. This gauge measures the force of static pressure and velocity pressure which is the total pressure. Note that the force of velocity pressure cannot be measured by itself. To measure velocity pressure we must measure the total pressure and measure the static pressure then subtract the difference which is velocity pressure.

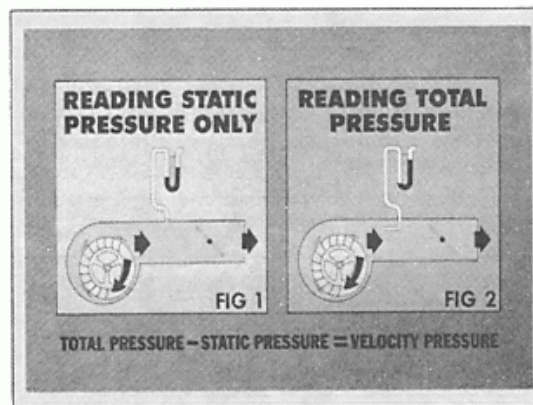


Figure 11

In place of taking two separate readings to determine the velocity pressure, connect the manometer as shown in Figure 12. On one side of the manometer static pressure is exerting its force on the fluid column. Opposing the static pressure on the other column of the manometer is the total pressure which consists of static pressure plus velocity pressure. The static pressure forces oppose each other and cancel each other out. The net result reading on the manometer is equal to the velocity pressure.

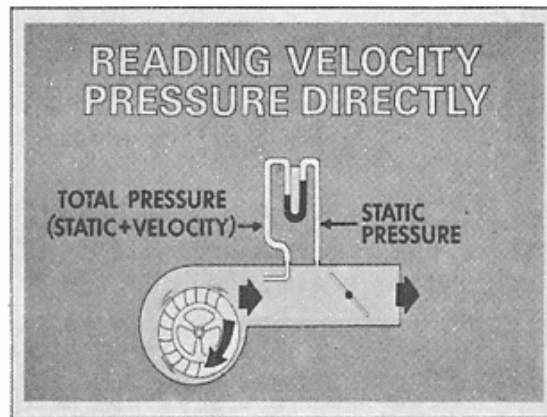


Figure 12

USING A PITOT TUBE

It is not necessary to drill two holes in a piece of duct work to measure velocity pressure. A single hole with a pitot tube and manometer can be used to measure the velocity pressure. The "Pitot Tube" is named after the French physicist Henri Pitot. As shown in Figure 13, the pitot tube is a tube within a tube. The 5/16" outer tube has eight .04" diameter holes equally spaced which sense static pressure. The static pressure will enter these holes and pass through the tube and exit a side outlet port. It is important to keep these small holes clean and unobstructed.

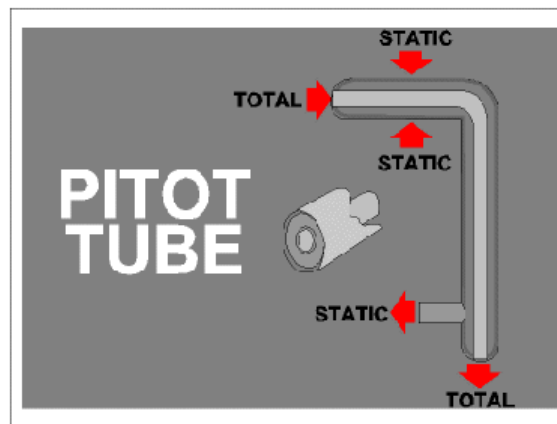


Figure 13

The total pressure of the duct enters the tip of the pitot tube which is faced directly into the air stream. Total pressure passes through a 1/8" O.D. inner tube and exits the bottom connection.

The pitot tube is available in various lengths ranging from 6" to 60" in length and are capable of measuring static pressure, total pressure or velocity pressure depending on how it is connected to the manometer.

Shown in Figure 14, the pitot tube and inclined manometer is connected to the duct system to measure velocity pressure. The total pressure port of the pitot tube is connected to the left side of the manometer. The static pressure port connects to the right side. Static pressure forces cancel each other out and the resultant velocity pressure is read in inches of water column.

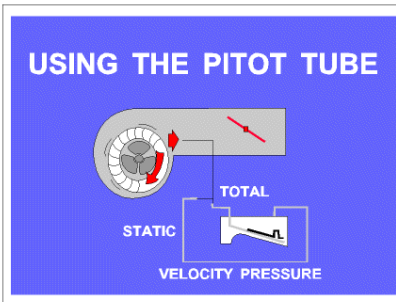


Figure 14

To obtain accurate readings make sure the pitot tube is facing the air stream directly. Point the static pressure outlet opposite the direction of air flow to position the pitot tube inside the duct.

Use a good quality hose connection to the manometer that resists kinking and is leak free.

TAKING TRAVERSE READINGS

Due to the fact that the velocity of air through a duct is never uniform, a traverse must be made to read the velocity pressure uniformly through a section of duct work. The traverse location should be in a straight run of duct at a location of at least ten small duct dimensions downstream and five small duct dimensions upstream of any turbulence. Turbulence may be caused by elbows, transitions, or take offs. This may be difficult to obtain on residential systems but is necessary to obtain accurate results. The more turbulence that is encountered, the greater the number of readings that must be obtained to ensure a true average velocity thru the duct.

The number of readings that must be taken in the traverse for rectangular duct is at a maximum of 6 inch squares. The reading is taken in the center of each square as shown by the "X" in Figure 15.

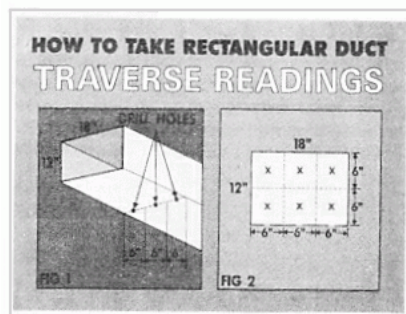


Figure 15

Remember the greater the number of readings taken, the greater the accuracy. The pitot tube is marked in graduated height columns on the outer tube for ease in positioning it within the duct work.

The traverse for round duct is more complex. Two holes must be drilled at right angles to each other as shown in Figure 16 on the left side. Then the readings must be taken at a specified depth along each diameter. Larger ducts will require more readings to ensure an accurate average velocity, see Figure 17. Although a traverse is time consuming, it is necessary to ensure accuracy. Without a certain degree of accuracy, you cannot rely on your results, therefore, the entire procedure would be useless. Strive for accuracy.

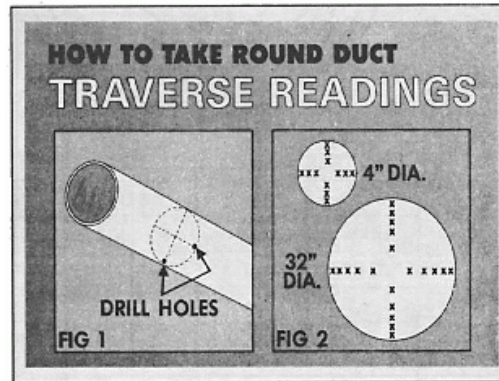
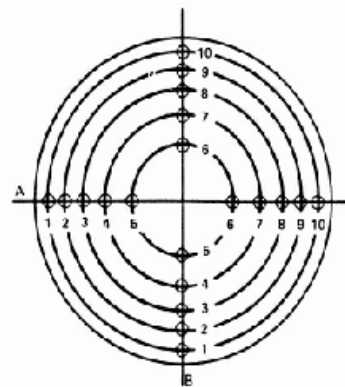


Figure 16



Depths to Insert
Pitot Tube for
Traverse Readings
on Round Ductwork

DUCT DIAM.	POINTS IN ONE DIAM.	DISTANCE FROM INSIDE OF DUCT (POINT A AND B) TO PITOT TUBE TIP									
		1	2	3	4	5	6	7	8	9	10
4"	5	—	—	1/4	5/8	1 1/4	2 7/8	3 1/2	5 7/8	—	—
6"	5	—	—	1/4	7/8	1 3/4	4 1/4	5 1/8	6 3/4	—	—
8"	6	—	—	3/8	1 1/4	2 3/8	5 5/8	6 7/8	7 3/4	—	—
9"	6	—	—	3/8	1 3/8	2 3/4	6 3/8	7 3/4	8 5/8	—	—
10"	8	—	3/8	1 1/8	2	3 1/4	6 3/4	8 1/8	9	9 3/4	—
12"	8	—	3/8	1 1/4	2	3 7/8	8 1/8	9	10 3/4	11 5/8	—
14"	10	3/8	1 1/8	2 1/8	3 1/4	4 3/4	9 1/4	10 7/8	12	12 7/8	13 5/8
16"	10	1/2	1 3/8	2 3/8	3 6/8	5 1/2	10 1/2	12 5/8	13 5/8	14 3/4	15 5/8
18"	10	1/2	1 1/2	2 5/8	4 1/8	6 1/8	11 7/8	14	15 3/8	16 1/2	17 5/8
20"	10	1/2	1 5/8	3	4 1/2	6 7/8	13 1/4	15 1/2	17 1/8	18 3/8	19 1/2
24"	10	5/8	2	3 1/2	5 1/2	8 1/4	15 7/8	18 1/2	20 1/2	22 1/8	23 3/8
28"	10	3/4	2 1/4	4 1/8	6 3/8	9 5/8	18 1/2	21 3/4	24	26 3/8	27 1/4
32"	10	7/8	2 5/8	4 3/4	7 1/4	11	21 1/8	24 3/4	27 1/4	29 3/8	31 3/8

FOR OTHER DUCT DIAMETERS USE THE FOLLOWING TABLE.

POINTS IN ONE DIAM.	CONSTANTS TO BE MULTIPLIED BY DUCT DIAMETER FOR DISTANCES OF PITOT TUBE TIP FROM INSIDE OF DUCT (POINT A AND B)									
	1	2	3	4	5	6	7	8	9	10
6	—	—	.0425	.1465	.2958	.7041	.8525	.9561	—	—
8	—	.0323	.1047	.1938	.3232	.6758	.8052	.8953	.9677	—
10	.0257	.0817	.1465	.2262	.3419	.6591	.7798	.8535	.9133	.9743

Figure 17

AIR FLOW CALCULATIONS

To calculate the air flow in cubic feet per minute, the area of the duct in square feet where the readings have been taken is multiplied by the average velocity in feet per minute. Remember, velocity is a time rate of linear motion of air in a given direction, and when multiplied by the area in square feet it yields the cubic feet per minute of air movement.

First we will discuss how to calculate the area of the duct, then we will convert the velocity pressure that is measured in inches of water column, to velocity in feet per minute.

For rectangle duct, the area in square feet is equal to the length in inches times the width of the duct in inches, divided by the 144 square inches there are in each square foot.

$$A = \frac{L \times W}{144}$$

For round duct, the area is equal to Pi times the diameter squared all divided by 4 times 144.

$$A = \frac{\pi D^2}{4 \times 144}$$

See Figure 18 &19.

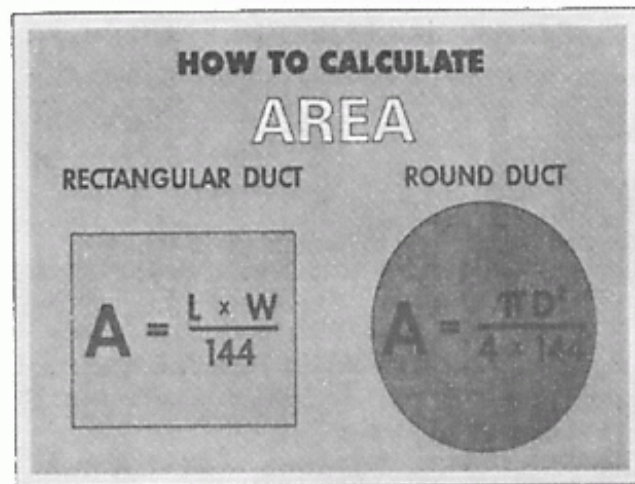


Figure 18

CONVERSION OF DUCT DIAMETER AREA	
Duct Diameter (inches)	Area (square feet)
4"	.0872
5"	.1363
6"	.1962
7"	.2671
8"	.3488
9"	.4415
10"	.5451
11"	.6596
12"	.7850
14"	1.0685
16"	1.3955
18"	1.7662
20"	2.1805
22"	2.6384
24"	3.1399
26"	3.6851
28"	4.2738
30"	4.9062
32"	5.5821
34"	6.3017
36"	7.0648

Figure 19

Next we need to convert the velocity pressure in inches of water column measured by the manometer to velocity in feet per minute. To convert use the following formula:

Velocity equals 4005 times the square root of the velocity pressure (Figure 20)

**HOW TO CALCULATE
VELOCITY**

$$V = 4,005 \sqrt{V_{\text{PRESSURE}}}$$

↑
↑

IN FEET / MINUTE IN INCHES OF WATER

Figure 20

This formula is based on standard air at the temperature of 70°F and a specific density of .075 pounds per cubic foot. Tables are provided to simplify the conversion as indicated in Figure 21.

Velocity Pressures							
VELOCITY PRESSURE (in. Wg)	VELOCITY (Ft/Min)	VELOCITY PRESSURE (in. wg)	VELOCITY (Ft/Min)	VELOCITY PRESSURE (in. wg)	VELOCITY (Ft/Min)	VELOCITY PRESSURE (in. wg)	VELOCITY (Ft/Min)
.01	400	.29	2150	.58	3050	1.28	4540
.02	565	.30	2190	.60	3100	1.32	4600
.03	695	.31	2230	.62	3150	1.36	4670
.04	800	.32	2260	.64	3200	1.40	4730
.05	895	.33	2300	.65	3250	1.44	4800
.06	980	.34	2330	.68	3300	1.48	4870
.07	1060	.35	2370	.70	3350	1.52	4930
.08	1130	.36	2400	.72	3390	1.56	5000
.09	1200	.37	2440	.74	3440	1.60	5060
.10	1270	.38	2470	.75	3490	1.64	5120
.11	1330	.39	2500	.78	3530	1.68	5190
.12	1390	.40	2530	.80	3580	1.72	5250
.13	1440	.41	2560	.82	3620	1.76	5310
.14	1500	.42	2590	.84	3670	1.80	5370
.15	1550	.43	2620	.85	3710	1.84	5430
.16	1600	.44	2650	.88	3750	1.88	5490
.17	1650	.45	2680	.90	3790	1.92	5550
.18	1700	.46	2710	.92	3840	1.96	5600
.19	1740	.47	2740	.94	3880	2.00	5660
.20	1790	.48	2770	.95	3920	2.04	5710
.21	1830	.49	2800	.98	3960	2.08	5770
.22	1880	.50	2830	1.00	4000	2.12	5830
.23	1920	.51	2860	1.04	4080	2.16	5890
.24	1960	.52	2880	1.06	4160	2.20	5940
.25	2000	.53	2910	1.12	4230	2.24	5990
.26	2040	.54	2940	1.15	4310	2.28	6040
.27	2080	.55	2970	1.20	4380		
.28	2120	.56	2990	1.24	4460		

NOTES: 1. Data for standard air (29.92 in. Hg and 70 F)
2. Data derived from the following Equation: $V = 4005 \sqrt{V_p}$

Figure 21

Manufacturers of pitot tubes also provide conversion charts for corrections at various air temperatures as shown in Figure 22. These corrections should be used where applicable at higher temperatures to reduce error and ensure accuracy.

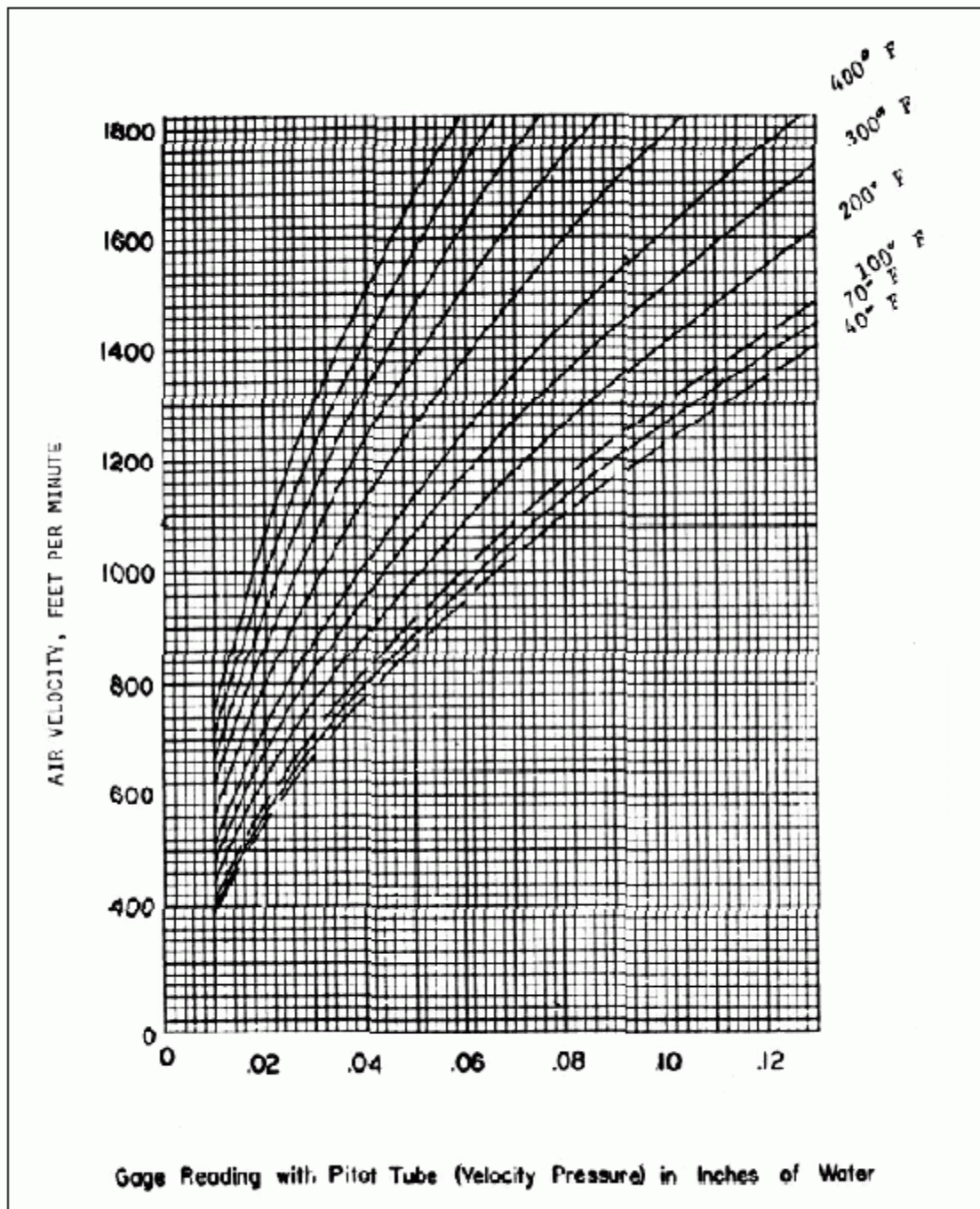


Figure 22

Particular emphasis must be placed on accurate readings in the traverse for lower velocity pressures. This is due to the fact that slight pressure variations account for rather large velocity changes especially at lower velocity pressure levels. For example:

.04" W.C. = 800 fpm

.05" W.C. = 895 fpm

The difference of .01 inches of W.C. pressure results in a velocity difference of 95 feet per minute which is substantial. This represents about an 11.8% difference in the velocity. At higher velocity pressures the difference is not as great as shown.

.25" W.C. = 2,000 fpm

.26" W.C. = 2,040 fpm

This difference of .01" of W.C. pressure at these higher levels accounts for about a 2% difference in the velocity.

It is also important to note that the velocity pressures taken in the traverse cannot be averaged together then converted to velocity due to the fact that it is a square root function. Mathematically you cannot average a square root. It must be converted to velocity in feet per minute and then averaged. Here is an example of why. First the correct method of determining the average velocity:

$$0.02 \text{ "W.C.} = 4,005\sqrt{0.02} = 566 \text{ fpm}$$

$$0.10 \text{ "W.C.} = 4,005\sqrt{0.10} = 1266 \text{ fpm}$$

$$\text{The average velocity} = \frac{566 + 1266}{2} = 916 \text{ fpm}$$

It would be incorrect to average the pressures of:

$$\frac{0.02 \text{ " + } 0.10 \text{ "}}{2} = 0.06 \text{ "}$$

Average Velocity Pressure

Then convert by the formula

$$4005\sqrt{0.06} = 981 \text{ fpm}$$

At the pressure level indicated in the example, this miscalculation has immediately introduced a 7% error in our calculation of air flow. As you can see air flow measurement is not an exact science and to be reasonably accurate you must reduce the chance of error wherever possible.

SAMPLE CALCULATION

As an example of an air flow calculation, we will use a rectangle duct 12 × 18 inches, sectioned into a proper traverse, and we then obtain a velocity pressure profile as shown in Figure 23. The six velocity

pressure readings are converted to velocity in feet per minute by the formula of $V = 4005\sqrt{Vp}$. Each velocity in feet per minute is then averaged to 935 feet/minute as shown in Figure 24. To calculate the cfm, the area of the 12 × 18 inch duct is equal to:

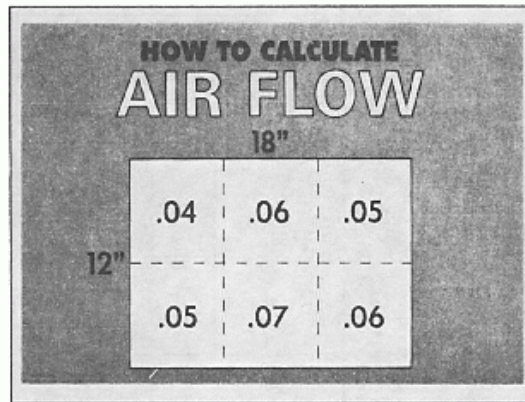


Figure 23

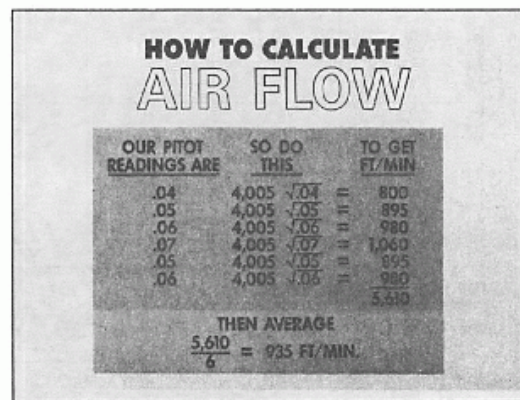


Figure 24

$$\text{Area} = \frac{12 \times 18}{144} = 1.5 \text{ sq. ft.}$$

The average velocity of 935 ft/min. times the duct area of 1.5 square feet equals 1,403 cubic feet per minute of air flow.

$$\text{cfm} = \text{area} \times \text{velocity}$$

$$\text{cfm} = 1.5 \text{ sq/ft} \times 935 \text{ ft/min.}$$

$$\text{cfm} = 1,403$$

MAKING CORRECTIONS

Normally the velocity of air is calculated at standard air conditions. Corrections are required when the temperature and/or elevation are other than standard air conditions of 70°F dry air at a barometric pressure of 29.92" mercury and a density of .075 lb/cu./ft.

The correction is made by using a density ratio factor found by dividing the actual air density by the standard air density as shown in Figure 25. The table gives the density ratio factors as a function of altitude and temperature.

$$\text{DENSITY RATIO} = \frac{\text{ACTUAL AIR DENSITY}}{\text{STANDARD AIR DENSITY}}$$

AIR TEMP. F	ALTITUDE IN FEET ABOVE SEA LEVEL								
	0	1000	2000	3000	4000	5000	6000	7000	8000
-50	1.292	1.247	1.202	1.158	1.116	1.078	1.03	.997	.960
0	1.152	1.171	1.071	1.033	.995	.959	.923	.889	.856
50	1.039	1.002	.965	.931	.897	.865	.833	.802	.772
70	1.000	.964	.930	.896	.863	.832	.801	.772	.742
100	.946	.912	.880	.848	.818	.787	.758	.730	.703
150	.869	.838	.808	.770	.751	.723	.696	.671	.646
200	.803	.774	.747	.720	.694	.663	.643	.620	.596
250	.747	.720	.694	.669	.645	.621	.598	.576	.555
300	.697	.672	.648	.624	.624	.602	.580	.538	.518

Figure 25

As shown in Figure 26, using a heating application at 3,000 feet of elevation with a supply air temperature of 150°F, the pitot tube traverse was used to calculate an air flow of 5,200 cubic feet per minute.

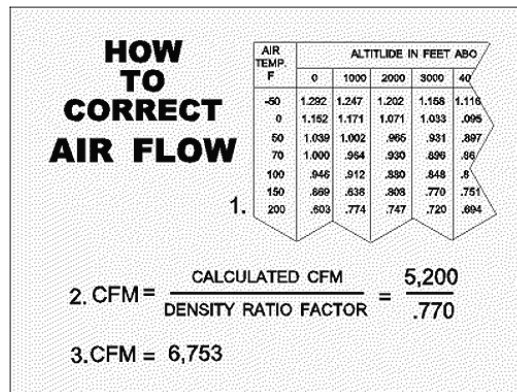


Figure 26

To correct the air quantity measured, divide the calculated cfm (5,200) by the air density ratio of .770 that is found on the chart by intersecting 3,000 feet with 150°F.

$$CFM = \frac{\text{Calculated CFM}}{\text{Air Density Ratio}} = \frac{5200}{.770} = 6,753$$

SINGLE-POINT APPROXIMATION

If the application or time restraints will not allow a proper traverse to be taken in a duct system, a method called single point approximation may be used. This method is used if only a "ball park" figure of air flow is all that is required. It will not be as accurate as a proper traverse. The velocity pressure is taken at the very center of the duct and converted to velocity in feet per minute. The velocity at this point is then multiplied by a factor of .9. The single point approximation should only be taken at a point of 10 small

duct dimensions downstream, and 5 small duct dimensions upstream of any turbulence source. The accuracy of this method if the reading is taken correctly is about plus or minus 5%.

MEASURING EXTERNAL STATIC PRESSURE

Blower cfm is rated at an external static pressure (ESP). External static pressure is the difference in static pressure between the supply opening and return opening of the unit. It is an indication of the total resistance to air flow from the return air grill to the supply air register. This restriction to air flow is affected by the duct design and layout, duct leakage, the types of grill and registers used, dirt condition of blower, coils, filters, and the amount of air that must be moved. An increase in the total external static pressure caused by a dirty filter or coil will reduce the system air flow.

To measure the external static pressure, a manometer and static sensing probe, static tracking tail, or the pitot tube is to be used. In Figure 27, a residential split system for cooling is coupled with a forced warm air furnace.

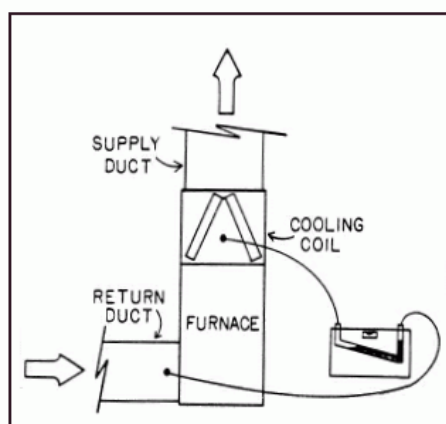


Figure 27

A 1/2" hole is drilled into the return air duct as close to the furnace as possible. The second hole is drilled between the furnace supply air opening and the cooling coil. Use caution not to drill into the coil. Before drilling make sure you check the coil configuration to see if it is a slab coil or an "A" coil.

Connect the supply side or the positive pressure connection to the left side of the manometer. Next, connect the return air pressure connection to the right side of the manometer. This is the negative connection port for manometer. The supply side connection will push the liquid column while the return side helps pull the fluid column. The net result is a reading on the manometer of the total system external static pressure. Make sure the coil is clean and note if the coil is wet or dry. Manufacturer's data will usually plot both conditions of the coil. Published data may be without a field supplied air filter or electric heater element in some pieces of equipment. Check the manufacturer's publication to see how the ratings were taken. An example of published ratings of blower cfm at a given external static pressure is shown in Figure 28.

Figure 28 Model 48KHA, KLA Air Delivery (cfm)* at Indicated External Static Pressure and Voltage

Model	UNIT VOLTS --- PHASE (60 Hz)	BLOWER MOTOR OR SPEED	COIL +	EXTERNAL STATIC PRESSURE (In. wg)																		
				208V								230V or 460V										
				0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	
KLA 118	208 - 230 -1	Low	He at	740	700	660	615	565	510	---	---	---	805	765	725	675	625	565	---	---	---	
			Coil	700	665	625	580	535	480	---	---	---	760	720	680	635	585	525	---	---	---	
		High	He at	795	750	705	660	610	555	---	---	---	870	825	780	735	685	630	---	---	---	
			Coil	745	705	665	620	570	520	---	---	---	810	775	730	690	640	590	---	---	---	
KLA 124	208 - 230 -1	Low	He at	895	850	800	750	700	645	---	---	---	950	905	855	800	745	680	---	---	---	
			Coil	865	820	775	725	675	620	---	---	---	920	875	825	770	715	650	---	---	---	
		High	He at	980	930	875	820	760	700	---	---	---	1030	975	920	865	810	750	---	---	---	
			Coil	940	895	845	790	730	665	---	---	---	985	935	885	830	770	720	---	---	---	
KHA 024	208 - 230 -1	Low	He at	995	925	890	855	815	780	---	---	---	1030	990	955	920	880	840	---	---	---	
			Coil	935	900	870	835	800	765	---	---	---	1000	965	935	890	860	820	---	---	---	
		High	He at	1125	1075	1030	980	930	880	---	---	---	1160	1115	1065	1015	965	915	---	---	---	
			Coil	1080	1035	990	950	900	855	---	---	---	1120	1075	1030	980	935	885	---	---	---	
KLA 130	208 - 230 -1	Low	He at	700	680	655	635	610	585	---	---	---	850	820	795	765	735	705	---	---	---	
			Coil	690	670	650	630	605	580	---	---	---	835	810	785	755	725	695	---	---	---	
		High	He at	1325	1270	1220	1170	1120	1070	---	---	---	1370	1320	1270	1220	1170	1120	1070	---	---	---
			Coil	1270	1220	1170	1120	1070	1020	---	---	---	1320	1270	1220	1170	1120	1070	1020	---	---	---
KHA 030	208 - 230 -1	Low	He at	1125	1070	1025	955	900	840	---	---	---	1175	1125	1075	985	925	855	---	---	---	
			Coil	1085	1035	985	925	870	815	---	---	---	1130	1075	1025	950	890	830	---	---	---	
		High	He at	1225	1165	1110	1040	980	915	---	---	---	1260	1200	1140	1070	1000	935	---	---	---	

			Co ol	11 75	11 20	10 65	10 05	94 5	88 5	---	---	---	12 05	11 55	11 00	10 40	98 5	92 5	---	---	---
										-	-	-							-	-	-
KLA 136	208 -	Low	He at	95 0	94 5	94 0	93 0	91 5	90 0	---	---	---	12 50	12 05	11 60	11 15	10 65	10 15	---	---	---
			Co ol	94 5	94 0	93 5	92 5	91 0	89 0	---	---	---	12 10	11 65	11 25	10 80	10 35	99 0	---	---	---
	230 -1	High	He at	15 70	15 00	14 25	13 55	12 80	12 00	---	---	---	16 10	15 40	14 70	14 00	13 30	12 55	---	---	---
			Co ol	14 75	14 10	13 45	12 75	12 05	11 40	---	---	---	15 10	14 50	13 90	13 25	12 60	11 90	---	---	---
KLA 136	208 / 230 -3	Low	He at	11 65	11 55	11 40	11 25	11 00	10 75	10 40	99 5	93 0	13 65	13 45	13 20	12 95	12 65	12 25	11 80	11 20	10 20
			Co ol	11 55	11 45	11 25	11 10	10 85	10 50	10 15	96 0	85 5	13 45	13 20	12 95	12 65	12 35	11 90	11 35	10 60	90 0
		High	He at	15 25	14 90	14 50	14 15	13 75	13 30	12 80	12 20	11 35	16 20	15 80	15 40	14 95	14 50	14 05	13 55	13 00	12 30
			Co ol	14 75	14 40	14 05	13 70	13 25	12 80	12 25	11 55	10 45	15 60	15 20	14 75	14 35	13 90	13 45	12 95	12 35	11 55
	460 -3	Low	He at	---	---	---	---	---	---	---	---	---	11 85	11 75	11 60	11 35	11 10	10 95	10 60	10 05	94 0
			Co ol	---	---	---	---	---	---	---	---	---	11 65	11 55	11 35	11 20	10 95	10 60	10 15	97 0	89 5
		High	He at	---	---	---	---	---	---	---	---	---	15 35	15 00	14 60	14 25	13 85	13 40	12 90	12 30	11 45
			Co ol	---	---	---	---	---	---	---	---	---	14 85	14 50	14 15	13 80	13 35	12 90	12 35	11 65	10 55
		Low	He at	12 80	12 60	12 40	12 15	11 90	11 60	---	---	---	15 10	14 80	14 45	14 00	13 40	12 75	---	---	---
KHA 036	208 -		Co ol	12 65	12 45	12 20	11 95	11 65	11 30	---	---	---	14 75	14 40	13 95	13 45	12 80	12 10	---	---	---
KHA 136	230 -1	High	He at	18 25	17 65	17 00	16 30	15 40	14 25	---	---	---	19 05	18 45	17 75	17 00	15 95	14 75	---	---	---
			Co ol	17 35	16 70	15 95	15 15	14 10	12 70	---	---	---	17 90	17 25	16 55	15 65	14 55	13 20	---	---	---
		Low	He at	12 75	12 70	12 60	12 40	12 20	11 95	11 65	11 35	11 00	15 05	14 90	14 70	14 45	14 15	13 75	13 30	12 80	12 30
			Co ol	12 70	12 60	12 45	12 25	12 05	11 75	11 45	11 10	10 75	14 90	14 70	14 45	14 15	13 75	13 30	12 85	12 35	11 85
KHA 036	208 / 230 -3	Med	He at	16 25	16 05	15 75	15 40	15 00	14 55	14 00	13 50	12 95	18 45	18 05	17 60	17 10	16 55	15 95	15 35	14 80	14 15
KHA 136			Co ol	15 90	15 65	15 30	14 90	14 45	13 95	13 50	13 00	12 45	17 70	17 25	16 75	16 25	15 75	15 20	14 65	14 05	13 50
		High	He at	20 35	19 80	19 20	18 55	17 85	17 15	16 45	15 70	14 95	21 30	20 70	20 10	19 40	18 70	18 00	17 25	16 45	15 70
			Co ol	19 15	18 60	18 00	17 40	16 75	16 10	15 45	14 80	14 10	19 95	19 40	18 75	18 15	17 45	16 80	16 15	15 45	14 75
KLA 142	208	Low	He at	85 5	85 0	83 5	82 0	79 5	76 0	---	---	---	10 35	10 25	10 10	99 5	97 5	95 0	---	---	---
			Co	85	84	83	81	79	75	---	---	---	10	10	10	99	96	93	---	---	---

	-	230 -1	High	ol	5	5	0	5	0	0	-	-	-	30	20	05	0	5	5	-	-	-
				He at	17 00	16 35	15 65	14 95	14 25	13 55	---	---	---	17 70	17 05	16 35	15 55	14 70	13 85	---	---	---
				Co ol	16 35	15 75	15 05	14 40	13 75	13 05	---	---	---	16 95	16 30	15 60	14 80	14 05	13 25	---	---	---
	208 / 230 -3	Low		He at	97 0	96 5	96 0	94 5	93 5	91 0	88 0	83 5	78 0	11 90	11 85	11 75	11 65	11 45	11 20	10 80	10 20	94 0
				Co ol	96 5	96 0	95 5	94 0	93 0	90 5	87 0	82 0	76 5	11 90	11 80	11 70	11 55	11 35	11 05	10 55	99 0	91 0
		High		He at	20 40	19 80	19 15	18 50	17 85	17 15	16 40	15 50	14 50	21 45	20 80	20 10	19 40	18 65	17 90	17 05	16 10	15 00
				Co ol	19 50	18 90	18 35	17 70	17 05	16 35	15 55	14 65	13 80	20 30	19 70	19 05	18 40	17 70	16 95	16 10	15 15	14 00
KHA 042	208 - 230 -1	Low		He at	14 10	13 85	13 55	13 15	12 55	11 75	---	---	---	15 80	15 30	14 75	14 20	13 60	12 90	---	---	---
				Co ol	13 90	13 65	13 30	12 80	12 15	11 20	---	---	---	15 35	14 85	14 35	13 80	13 15	12 40	---	---	---
		High		He at	17 05	16 50	15 90	15 25	14 50	13 65	---	---	---	17 70	17 10	16 45	15 75	15 00	14 15	---	---	---
				Co ol	16 50	15 90	15 35	14 65	13 90	13 00	---	---	---	17 05	16 40	15 80	15 10	14 35	13 45	---	---	---
	208 / 230 -3	Low		He at	14 05	14 00	13 95	13 85	13 65	13 35	12 95	12 40	11 75	16 50	16 35	16 10	15 85	15 45	15 00	14 45	13 80	13 05
				Co ol	14 00	13 95	13 85	13 70	13 45	13 10	12 60	12 05	11 45	16 30	16 05	15 75	15 40	14 95	14 45	13 85	13 20	12 50
		High		He at	17 25	17 10	16 85	16 55	16 15	15 65	15 05	14 40	13 70	19 35	18 85	18 35	17 80	17 30	16 70	16 10	15 40	14 55
				Co ol	17 05	16 85	16 55	16 15	15 70	15 15	14 55	13 90	13 20	18 70	18 20	17 70	17 20	16 65	16 10	15 50	14 70	13 60
KLA 148	208 - 230 -1	Low		He at	11 80	11 70	11 60	11 40	10 90	98 0	---	---	---	13 50	13 40	13 30	13 10	12 75	11 90	---	---	---
				Co ol	11 75	11 65	11 55	11 30	10 75	96 0	---	---	---	13 45	13 35	13 25	13 00	12 55	11 20	---	---	---
		High		He at	17 80	17 20	16 60	16 10	15 50	15 00	---	---	---	19 20	18 45	17 70	16 96	16 25	15 50	---	---	---
				Co ol	17 70	17 10	16 45	15 90	15 25	14 70	---	---	---	18 60	17 90	17 25	16 55	15 85	15 15	---	---	---
KLA 148	208 / 230 -3	Low		He at	12 00	11 95	11 90	11 80	11 70	11 50	11 45	11 35	11 15	14 20	14 10	14 00	13 90	13 85	13 70	13 55	13 30	13 00
				Co ol	11 95	11 90	11 80	11 70	11 60	11 45	11 40	11 30	11 10	14 15	14 05	13 95	13 85	13 80	13 65	13 50	13 20	12 85
		Med		He at	18 05	18 00	17 85	17 65	17 35	17 00	16 65	16 25	15 85	20 80	20 50	20 15	19 70	19 20	18 65	18 05	17 45	16 80
				Co ol	18 00	17 90	17 70	17 45	17 15	16 80	16 40	16 05	15 65	20 50	20 20	19 75	19 30	18 80	18 20	17 65	17 05	16 40
		High		He at	22 00	21 55	21 10	20 55	20 00	19 40	18 80	18 15	17 55	23 25	22 75	22 20	21 60	20 95	20 30	19 65	18 95	18 25
				Co	21	21	20	20	19	18	18	17	17	22	22	21	20	19	19	18	18	17

			ol	55	10	60	05	50	90	35	75	10	65	15	60	00	40	75	10	40	70
		Low	He	---	---	---	---	---	---	---	---	---	15	14	14	14	14	13	13	13	12
			at	-	-	-	-	-	-	-	-	-	00	80	60	35	10	80	50	25	95
			Co	---	---	---	---	---	---	---	---	---	14	14	14	14	13	13	13	13	12
			ol	-	-	-	-	-	-	-	-	-	90	70	50	25	95	70	40	10	80
		High	He	---	---	---	---	---	---	---	---	---	20	19	19	18	18	17	17	16	15
			at	-	-	-	-	-	-	-	-	-	40	95	50	95	35	75	10	45	80
			Co	---	---	---	---	---	---	---	---	---	20	19	19	18	17	17	16	16	15
			ol	-	-	-	-	-	-	-	-	-	00	60	10	55	95	35	70	10	40
	460 -3																				
		Low	He	16	16	16	15	14	14	---	---	---	17	17	16	16	15	14	---	---	---
			at	90	50	00	45	80	20	-	-	-	90	30	65	00	30	50	-	-	-
			Co	16	16	15	15	14	13	---	---	---	17	16	16	15	14	14	---	---	---
			ol	85	40	85	25	55	90	-	-	-	50	90	30	65	95	10	-	-	-
		High	He	18	18	17	16	16	15	---	---	---	19	19	18	17	16	15	---	---	---
			at	90	20	60	90	25	60	-	-	-	75	00	20	45	65	90	-	-	-
			Co	18	18	17	16	16	15	---	---	---	19	18	17	16	16	15	---	---	---
			ol	80	10	45	70	00	30	-	-	-	15	45	70	96	25	50	-	-	-
KHA 048	208 - 230 -1																				

The total external static pressure should be below the maximum published by the manufacturer for a particular piece of equipment. (Figure 29) If the total external static pressure is greater than the published value, low air flow is indicated. This could be a result of problems in the supply or the return side of the duct. To check the supply duct, connect the manometer with a check of the static pressure as shown in Figure 30.

Rated Cooling and Heating Airflows				
MODEL 48-	COOLING		HEATING	
	Rated Airflow (cfm)*	ESP (in. wg)	Rated Airflow (cfm)*	Maximum ESP (in. wg)*
KLA118310BE	630	0.10	505	0.30
KLA124310BE	800	0.10	505	0.30
KHA024310BF	800	0.10	947	0.30
KLA130310BE	1000	0.15	462	0.30
KHA030310BF	1000	0.15	947	0.30
KLA136310BE	1200	0.15	758	0.30
KLA136510CE	1200	0.15	758	0.65
KLA136610CE	1200	0.15	758	0.65
KHA136310BE	1200	0.15	1155	0.30
KHA136510CE	1200	0.15	1155	0.65
KHA036310BF	1200	0.15	1445	0.30
KHA036510CF	1200	0.15	1445	0.65
KLA142310BE	1400	0.15	695	0.30
KLA142510CE	1400	0.15	695	0.65
KHA042310BF	1400	0.15	1445	0.30
KHA042510CF	1400	0.15	1445	0.65
KLA148310BE	1600	0.20	925	0.30
KLA148510CE	1600	0.20	925	0.65
KLA148610CE	1600	0.20	925	0.65
KHA048310BF	1600	0.20	1445	0.30
KHA048510CF	1600	0.20	1445	0.65
KLA160310BE	2000	0.20	1155	0.30
KHA060310BF	2000	0.20	1735	0.30

ESP— External Static Pressure

*Rated in accordance with U.S. Government D.O.E. test procedures and/or ARI Standard 210-81.

Figure 29

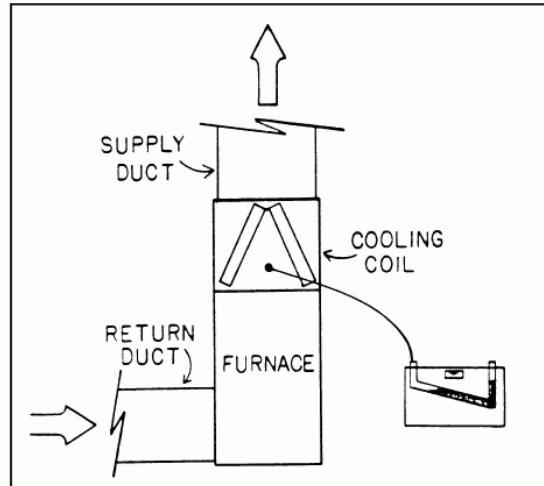


Figure 30

The maximum supply static pressure is approximately .45-.50 inches water column pressure. Pressures above this indicate problems in the supply air. Refer to the manufacturer's published data for the maximum limits.

Connecting the manometer as shown in Figure 31 will be down stream of the cooling coil and thus eliminating its effect. A pressure reading at this point in the duct system is a check of the supply duct and registers. A reading greater than approximately 0.15 inches of water column pressure is an indication of problems in the supply duct or registers.

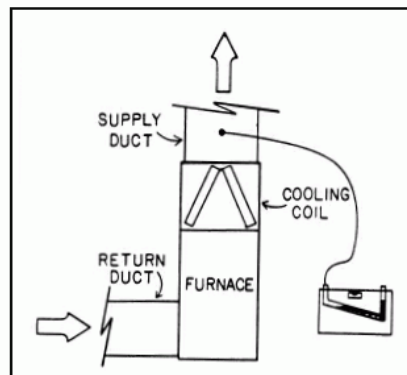


Figure 31

To check the return duct and registers, connect the manometer as shown in Figure 32. This connection will be a negative pressure and must connect to the right port opening of the manometer.

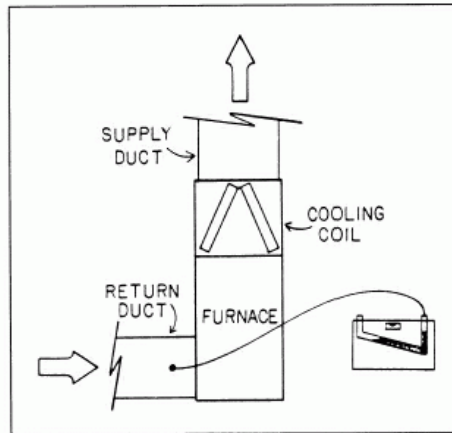


Figure 32

A reading in excess of approximately .10 inches of water column pressure indicates a problem in the return duct side. This could be caused by undersized duct, undersized grill or blocked return air.

CHECKING STATIC PRESSURE DROP

Another method of air flow measurement is to check the static pressure drop across the indoor coil and compare this to the manufacturer's published data.

The coil offers a known resistance to air flow, so the pressure drop across it is a good indicator of how much air is passing through it. The coil should be kept clean. It is also important to note if the coil is wet or dry. At a given cfm, a wet coil offers a greater pressure drop than a dry coil due to the resistance to air flow created by moisture on the coil surface. The manometer is connected across the coil as shown in Figure 33.

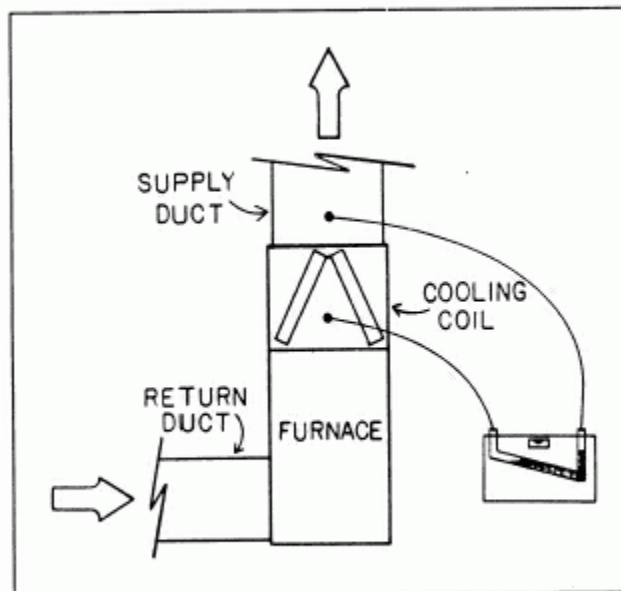


Figure 33

Before drilling across the coil, make sure you check the coil configuration to see if it is a "slab" coil or an "A" coil.

The coil pressure drop will increase as the air quantity increases as shown in Figure 34.

COIL STATIC PRESSURE DROP (in wg)									
MODEL	AIR QUANTITY (Cfm)								
28RD015	300	400	500	600	—				
	0.057	0.096	0.147	0.213					
	0.035	0.059	0.091	0.132					
28RD,RN018	400	500	600	700	—				
	0.096	0.147	0.213	0.315					
	0.059	0.091	0.132	0.195					
28RD,RN019	600	700	800	900	1000	—			
	0.140	0.185	0.240	0.290	0.335				
	0.098	0.130	0.168	0.203	0.235				
28RD,RN024	600	700	800	900	1000	—			
	0.140	0.185	0.240	0.290	0.335				
	0.098	0.130	0.168	0.203	0.235				
28RD,RN025	700	800	900	1000	1100	1200	—		
	0.114	0.147	0.186	0.234	0.276	0.327			
	0.071	0.091	0.115	0.145	0.171	0.202			
28RD030 28RD,RN130	700	800	900	1000	1100	1200	—		
	0.143	0.184	0.233	0.300	0.345	0.409			
	0.089	0.114	0.144	0.181	0.214	0.253			
28RD,RN036 28RD136	900	1000	1100	1200	1300	—			
	0.167	0.208	0.249	0.300	0.348				
	0.103	0.128	0.155	0.185	0.215				
28RD,RN042 28RD,RN142	1100	1200	1300	1400	1500	1600	—		
	0.147	0.174	0.207	0.240	0.288	0.309			
	0.091	0.108	0.128	0.149	0.178	0.191			
28RD,RN242	1000	1100	1200	1300	1400	1500	1600	—	
	0.15	0.17	0.21	0.23	0.27	0.30	0.34		
	0.10	0.12	0.14	0.17	0.18	0.20	0.24		
28RD,RN043 28RD,RN143	1200	1300	1400	1500	1600	1700	1800	—	
	0.16	0.18	0.21	0.24	0.27	0.30	0.33		
	0.11	0.13	0.14	0.16	0.18	0.20	0.22		
28RD048	1200	1300	1400	1500	1600	—			
	0.200	0.230	0.262	0.295	0.338				
	0.142	0.163	0.183	0.207	0.239				
28RD248	1100	1200	1300	1400	1500	1600	1700	—	
	0.17	0.19	0.23	0.25	0.27	0.30	0.35		
	0.15	0.16	0.17	0.18	0.19	0.22	0.25		
28RD,RN148	1200	1300	1400	1500	1600	1700	1800	—	
	0.149	0.179	0.200	0.223	0.257	0.291	0.320		
	0.106	0.126	0.142	0.157	0.180	0.205	0.225		
28RD049	1400	1500	1600	1700	1800	1900	2000	—	
	0.17	0.19	0.21	0.23	0.25	0.27	0.30		
	0.11	0.13	0.14	0.16	0.19	0.18	0.21		
28RD,RN057	1600	1700	1800	1900	2000	2100	2200	—	
	0.21	0.23	0.25	0.27	0.30	0.33	0.36		
	0.14	0.15	0.17	0.18	0.21	0.23	0.24		
28RD,RN060	1800	1700	1800	1900	2000	2100	2200	—	
	0.170	0.190	0.209	0.230	0.255	0.270	0.290		
	0.115	0.129	0.141	0.158	0.174	0.184	0.199		
28RD,RN061	1800	1900	2000	2100	2200	2300	2400	—	
	0.13	0.14	0.17	0.18	0.20	0.22	0.27		
	0.10	0.11	0.13	0.14	0.15	0.16	0.17		

Wet Coil — Roman Type
Dry Coil — Italic Type

Figure 34

ANEMOMETERS

An anemometer as shown in Figure 35 is another instrument widely used to measure air flow. The word anemometer comes from two words. The first part of the word comes from the Greek word "anemo" which means wind. The second part of the word is "meter" which means measure of. As the word implies, it

measures the wind. This instrument will measure the velocity of air in feet. The device has vanes that rotate on impact with a stream of air. When the anemometer is timed for one minute, it reads velocity in feet per minute. This device will give a good average velocity of air at a stationary point over a time of one minute. Taking the readings at a stationary point in a traverse for one minute reduces measurement error. To be accurate it must be held directly in the air stream, and the flow of air must not be restricted by your hand, arm or head. The instrument is sensitive and must be handled carefully. Do not touch the rotating blades as you will change the pitch of the blade and throw the meter out of calibration. Keep the instrument clean and calibrated for accurate results.

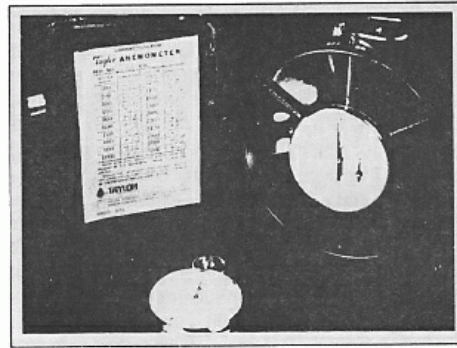


Figure 35

The anemometer will read the actual feet per minute at the existing air specific density. If correction is desired to standard air, multiply the anemometer reading by the air density ratio. If the air density at 70°F was 0.0625 pounds per cubic foot, and the measure air flow was determined to be 8,300 cfm, the standard air flow would be as follows:

$$\text{STD CFM} = \frac{(\text{Actual Density})}{(\text{Standard Density})} \times \text{CFM Actual}$$

$$\text{STD CFM} = \frac{(0.0625)}{(0.075)} \times 8,300$$

$$\text{STD CFM} = 6,916$$

The anemometer has three scales which measure feet as shown in Figure 36. The outer scale reads directly from 0 to 100 feet, a 100 foot scale on the left reads 0-1,000 feet, and the 1,000 foot scale on the right measures 0 to 10,000 feet. Notice on the right side of Figure 36, that the meter has a brake for the clocking mechanism. Set to the "on" position, the anemometer will measure the feet of air movement. Set at the "off" position the vanes will continue to rotate freely but the clocking mechanism is stopped. Never try to stop the brake with your finger or a pencil as this will be harmful to the instrument.

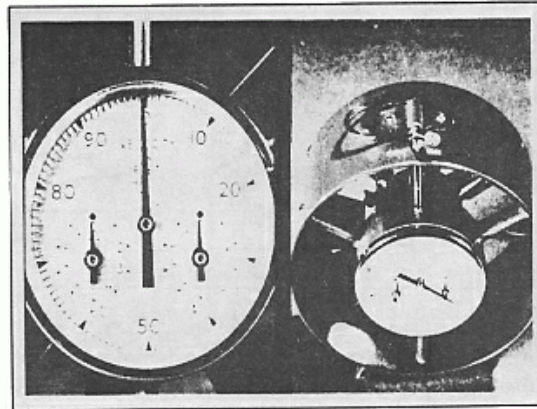


Figure 36

Located on the right side of the dial face is a reset lever to reset all the dials back to zero. The brake must be placed in the off position before resetting the dials. This prevents stripping the instrument gears.

To measure the airflow, set the brake to the off position, this stops the clocking mechanism. Push the zero reset lever to bring the dials back to zero.

Place the anemometer in the air stream in its first traverse position. When the instrument is up to speed, turn the brake to the "on" position and time the anemometer for one minute. At the end of one minute, turn the brake to the "off" position, remove the anemometer and record the reading. Turn the anemometer on and off only when placed in the air stream. The instrument should be timed for one minute in a stationary position to yield greater accuracy. Timing the anemometer for 30 seconds and then multiplying the reading by two simply increases your error. (Figure 37)

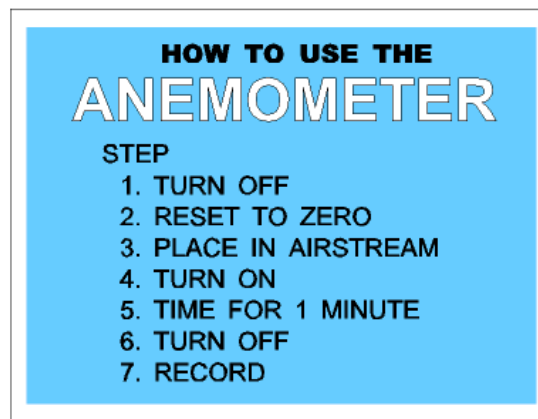


Figure 37

The anemometer dial face in Figure 38 was clocked for one minute. To read the instrument, start with the 1,000's dial on the right. It is reading more than 1,000 feet but less than 2,000 feet, so record 1,000 feet. The 100's dial on the left is reading more than 800 feet but less than 900 feet. Record 800 feet.

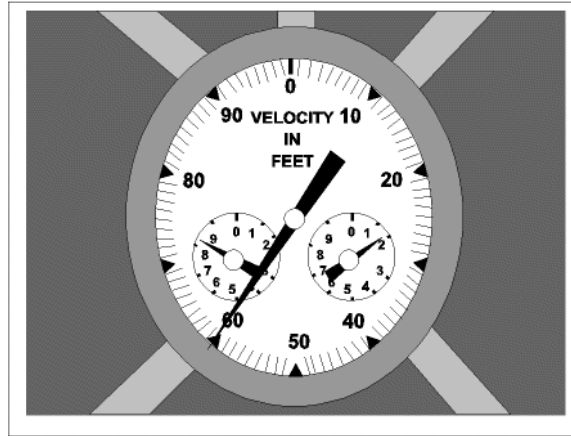


Figure 38

The direct dial is reading 60 feet. The velocity read is 1,860 feet per minute. To take into account bearing drag and friction, the instrument is calibrated against a known velocity. The calibration chart will correct the readings. In the example of 1,860 feet per minute, the closest correction factor is for 1,800 feet. Our reading would have to be increased 92 feet. The corrected velocity is $1,860 + 92 = 1,952$ feet per minute. (Figure 39)

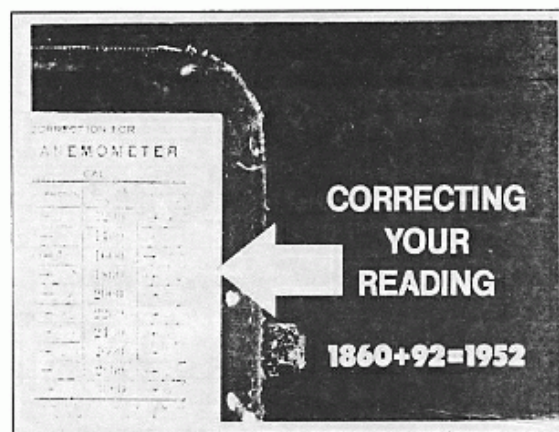


Figure 39

Using a 12×18 inch duct in our example, first record the anemometer readings at each point in the traverse. Then correct each reading according to the instruments correction chart. Average the corrected velocity readings and multiply this times the area of the duct or opening in square feet. If the average corrected velocity was 1,858 feet per minute and the duct area was 1.5 square feet, the cfm would be equal to 2,787.

If the anemometer is used at a register or grill, the free area of the opening must be used. Free area of a grill is the total area less the area taken up by the grill itself. To get the proper air flow, multiply the average velocity times the free area of the grill which is found in the grill manufacturer's catalog.

Figure 40 is an example of typical grill and approximate free areas. To be accurate, refer to the grill manufacturer's catalog. If the free area data is not available, a hood is often used to capture the air, reduce outlet turbulence and direct the air flow through a one square foot opening. An anemometer placed at this location will now read the velocity of air in feet per minute at a one square foot area opening. The meter now reads directly in cfm.

Residential Air Distribution

SUPPLY - FLOOR OUTLETS - PERIMETER

CFM	SIZE (IN.)	APPROX. SPREAD (FT.)	FACE VELOCITY (FPM)	FREE AREA (SQ. IN.)
70	2 1/4 x 10	8	535	18.6
80	2 1/4 x 12	10	565	21.1
100	2 1/4 x 14	11	610	23.6
110	4 x 10	10	500	37.4
135	4 x 12	13	500	39.0
175	4 x 14	14	555	45.5

SUPPLY - LOW SIDE WALL - PERIMETER

CFM	SIZE (IN.)	APPROX. SPREAD (FT.)	FACE VELOCITY (FPM)	FREE AREA (SQ. IN.)
80	10 x 6	13	430	26.7
100	12 x 6	10	440	32.6
120	14 x 6	8	450	38.4

SUPPLY - BASEBOARD

CFM	SIZE (FT.)	APPROX. SPREAD (FT.)	OUTLET VELOCITY (FPM)	FREE AREA (SQ. IN.)
8	2	7.5	430	26.8

SUPPLY - HIGH SIDE WALL

CFM	SIZE (IN.)	HORIZ. THROW (FT.)	FACE VELOCITY (FPM)	FREE AREA (SQ. IN.)
30	10 x 4	8	390	29.0
125	10 x 6	10	415	43.3
150	12 x 6	10	410	52.7
155	14 x 6	9.5	375	62.1

SUPPLY - ROUND CEILING OUTLETS

CFM	SIZE (IN.)	HORIZ. THROW (FT.)	OUTLET VELOCITY (FPM)	FREE AREA (SQ. IN.)
45	5	3	500	12.2
105	8	5	580	25.1
185	10	7	580	43.8
285	12	8.5	575	65.7
425	14	10.5	600	81.9

SUPPLY - SQUARE CEILING OUTLETS

CFM	SIZE (IN.)	HORIZ. THROW (FT.)	OUTLET VELOCITY (FPM)	FREE AREA (SQ. IN.)
50	6 x 6	3.5	450	15.4
135	8 x 8	5	550	35.1
250	10 x 10	6	620	58.1
325	12 x 12	7	550	85.1

RETURN AIR GRILLES

CFM	SIZE (IN.)	FREE AREA (SQ. IN.)
100	12 x 6	30.4
125	12 x 6	44.4
170	12 x 8	61.0
145	14 x 6	52.4
200	14 x 8	72.0
245	24 x 6	65.6
335	24 x 8	122.0
310	30 x 6	110.8
425	30 x 8	152.0

VERTICAL STACKS

SUPPLY CFM	STACK SIZE (IN.)	RETURN CFM
100	3 1/4 x 10	75
125	3 1/4 x 12	90
150	3 1/4 x 14	110

PANED JOIST (16 IN. O.C.)

RETURN CFM	NOMINAL JOIST (IN.)	ACTUAL JOIST (IN.)
375	8	7 1/2
575	10	9 1/2

DUCT SIZING

CFM	SUPPLY (IN.)		RETURN (IN.)		CFM
	ROUND	REC-TANGULAR	ROUND	REC-TANGULAR	
50	5	3 x 6	6	5 x 6	50
100	6	3 x 6	7	8 x 6	100
150	7	3 x 6	8	3 x 6	150
200	8	8 x 8	10	10 x 8	200
300	9	10 x 8	13	12 x 8	300
400	10	12 x 8	12	14 x 8	400
500	12	14 x 8	12	16 x 8	500
600	12	16 x 8	14	18 x 8	600
700	12	18 x 8	14	20 x 8	700
800	14	20 x 8	14	24 x 8	800
900	14	22 x 8	16	26 x 8	900
1000	16	24 x 8	16	30 x 8	1000
1100	16	26 x 8	18	34 x 8	1100
1200	16	28 x 8	18	36 x 8	1200
1300	16	30 x 8	18	20 x 10	1300
1400	18	32 x 8	18	30 x 10	1400
1500	18	28 x 10	20	32 x 10	1500
1600	18	30 x 10	20	34 x 10	1600

Based on .08 inch WG/100 ft. for supply ducts and .05 inch WG for return ducts.

Figure 40

DEFLECTING-VANE ANEMOMETERS

In the methods of air flow measurement mentioned so far, conversions, timing, corrections, reference charts or calculations had to be performed to determine air velocity. An instrument called a deflecting vane anemometer is used to give a direct reading of air velocity, thus eliminating many calculations. A sample of the air stream being measured passes through the velometer causing a sensitively balanced vane to deflect and indicate the air velocity in feet per minute. Various attachments to the instrument called jets and orifices are used for supply and return air stream which are read at various scales on the meter face. (Figure 41)

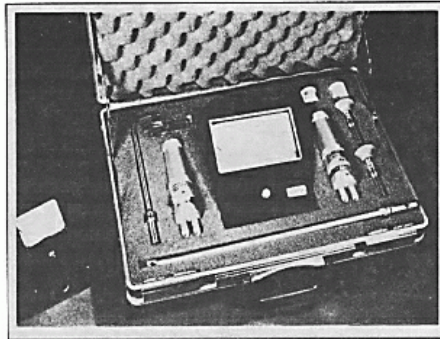


Figure 41

This meter is calibrated for measurement of standard air and will have correction factors for nonstandard air measurement.

HOT-WIRE ANEMOMETERS

Air velocity is measured by yet another instrument called a hot wire anemometer. This device will also give a direct reading of velocity in feet per minute. A sensing probe as shown in Figure 42, is placed into the air stream. The probe contains a small resistance heater. As the air passes across the heater, the temperature of the heater changes. The change in heater temperature changes its resistance which determines the current flow through a coil of wire controlling the meter needle position. The needle deflecting is calibrated to read out in feet per minute of air flow.

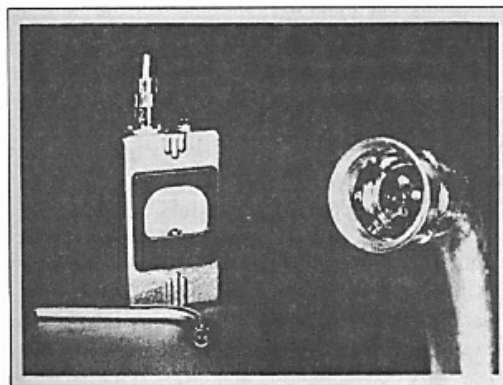


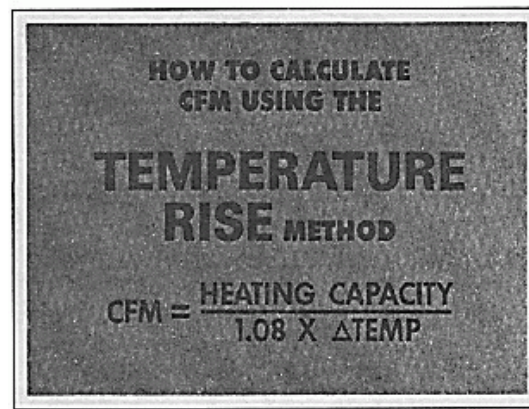
Figure 42

When the velocity increases, more air flows across the heater which is cooled. The cooler heater has less resistance which results in a greater current flow through the coil of wire. As the current flow increases, the resultant increases in coil magnetic strength deflects the needle to measure a greater velocity.

Today many different styles of anemometers are available in direct digital readout formats. This adds to the accuracy and convenience of the user.

USING THE TEMPERATURE RISE METHOD TO CALCULATE CFM

Another method of air measurement often used in the field is the temperature rise method. The test instruments required are an accurate ammeter, voltmeter and digital thermometer or thermocouple. When a sensible heat source such as electric resistance heater or fossil fuel furnace is available, this method of air measurement may be used and is quite accurate. The formula for determining the air flow is shown in Figure 43.



HOW TO CALCULATE
CFM USING THE
**TEMPERATURE
RISE METHOD**

$$CFM = \frac{HEATING\ CAPACITY}{1.08 \times \Delta TEMP}$$

Figure 43

Cfm is equal to the heating capacity divided by a conversion factor of 1.08 times the temperature rise between the return and supply air temperatures. The conversion factor of 1.08 converts all the units of measurement taken in the formula to cubic feet per minute. It is derived from standard air conditions by multiplying the specific heat of air .24 Btu/lb/°F, times the specific density of air .075 lb/cu ft, times 60 minutes per hour.

Before using the temperature rise method, make sure the system has run long enough to reach a stabilized condition. The system must run continuously and not cycle off from the condition space thermostat. To arrive at accurate results, measure several temperature readings in both the supply and return air for a representative average temperature. Make sure the temperature readings are taken "out of sight" of the heat source so that radiant heat will not affect the readings.

SAMPLE CALCULATION

In our first example, let's measure air flow across an electric resistance heater.

Referring to Figure 44, we first measure the entering and leaving air temperatures. Remember to place the leaving temperature sensor out of the direct sight line of the heater elements or the radiant heat will cause erroneous readings. Next, measure the voltage and the total current draw of the air handler. This can be measured at the unit disconnect or unit terminal block, whichever is more convenient. The total current measured will include the electric heater elements and the motor current which also adds heat to the air. When all the data has been collected, it is applied to the temperature rise formula to calculate the cfm of air movement. (Figure 45)

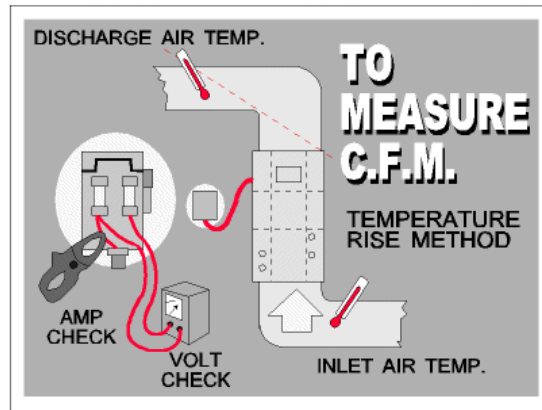


Figure 44

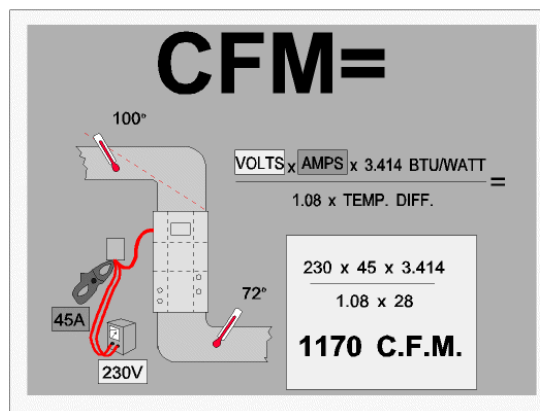


Figure 45

Cfm is equal to volts times amps times 3.414 (Btu's per watt) all divided by 1.08 times the temperature difference between the supply and return air.

In the example shown in Figure 45, the voltage was 230, the total current draw of the unit was 45 amps and the temperature rise was 28°F. Applying these values to the formula, the calculated cfm would be 1,170 cfm. When three phase heaters are used, the formula is as follows:

$$CFM = \frac{\text{Avg. Volts} \times \text{Avg. Amps} \times 1.73 \times 3.414 \text{ Btu / Watt}}{1.08 \times \Delta T}$$

USING CHARTS AND TABLES

Charts may also be found which plot the relationship of heater wattage versus temperature rise to indicate cfm of air movement as shown in Figure 46.

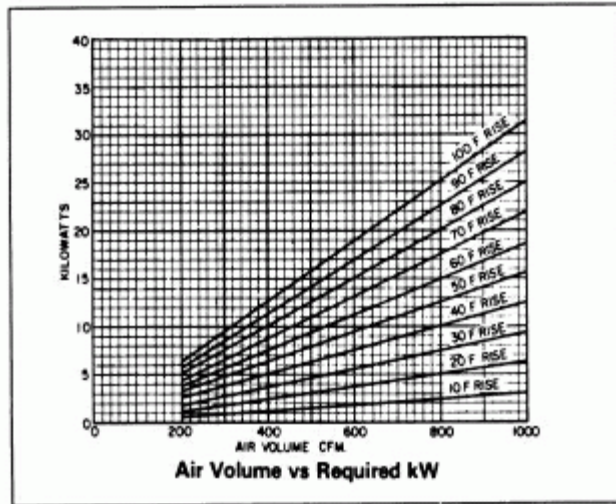


Figure 46

It is obvious from looking at the chart that at a given heat output or KW, as the temperature rise decreases, the cfm increases. As the temperature rise increases, this indicates lower air flow at a given heating capacity.

The temperature rise method is also used in fossil fuel furnaces. Manufacturers will stamp on the nameplate of the unit the required temperature rise across the heating section to ensure proper air flow. Check to make sure the heating input to the furnace is correct. This is accomplished by checking the published manifold pressure or clocking the gas meter. The manufacturer takes the combustion efficiency into account when publishing the table.

Tables such as shown in Figure 47, indicate the cfm of air movement for a given machine at the rated heating input and temperature rise. Tables and charts of this type make the temperature rise method of air flow very convenient to use.

Figure 47 Air Delivery (cfm) at Indicated Temperature Rise and Rated Heating Input

Model 48	HT G INP UT (Bt uh)	TEMPERATURE RISE (F)																				
		35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
KLA118	40, 000	79 4	75 1	71 2	67 8	64 6	61 7	59 1	56 7	54 5	52 4	50 5	48 7	47 1	45 5	44 1	42 7	---	---	---	---	---
KLA124	40, 000	79 4	75 1	71 2	67 8	64 6	61 7	59 1	56 7	54 5	---	---	---	---	---	---	---	---	---	---	---	
KHA024	75, 000	---	---	---	---	12 12	11 58	11 09	10 63	10 22	98 3	94 7	91 4	88 3	85 4	82 7	80 9	77 8	---	---	---	---
KLA130	40, 000	79 4	75 1	71 2	67 8	64 6	61 7	59 1	56 7	54 5	52 4	50 5	48 7	47 1	45 5	---	---	---	---	---	---	
KHA030	75, 000	---	---	---	12 71	12 12	11 58	11 09	10 63	10 22	98 3	94 7	91 4	88 3	85 4	---	---	---	---	---	---	

KHA136	60,000	1190	1126	1068	1016	969	926	887	850	817	786	758	731	706	683	---	---	---	---	---	---	---
KHA036/136	100,000	1984	1877	1781	1694	1615	1543	1478	1417	1362	1310	1263	1218	1177	1138	1102	1068	1036	1006	978	951	926
KHA036	125,000	---	---	---	2117	2019	1930	1846	1771	1701	1638	1579	1523	1472	1423	1378	1336	1296	1258	1223	1189	1158
KLA142	60,000	1190	1128	1068	1016	969	926	887	850	817	786	758	731	706	683	661	641	622	604	587	571	556
KHA042	125,000	---	---	---	---	---	1930	1846	1771	1702	1638	1579	1523	1482	1423	1378	1326	1296	1258	1223	1189	---
KLA148	80,000	1587	1502	1425	1355	1292	1235	1182	1134	1089	1048	1010	975	942	911	---	---	---	---	---	---	---
KHA048	125,000	---	---	2326	2117	2019	1930	1846	1771	1702	1638	1579	1523	1472	1423	1378	1336	1296	---	---	---	---
KLA160	100,000	1984	1877	1781	1694	1615	1543	1478	1417	1362	1310	1263	1218	1177	1138	1102	---	---	---	---	---	---
KHA060	150,000	---	---	---	---	---	2325	2226	2135	2051	1974	1902	1835	1773	1715	1660	1609	1561	1516	1473	1433	1395



NOTE: Bolder ratings in table fall below the approved temperature rise capability of the unit within the operating voltage range for all voltage range of the unit. Dashed areas of the table fall beyond the air delivery options for each size unit.

CALCULATING THE HEATING INPUT

If data is not available for a particular heating system and the temperature rise method is to be used in determining air flow, the input heating capacity must be calculated. Use a stop watch and time the revolution of either the half or the two cubic foot dials of a gas meter. Make sure that the only gas flowing through the meter is to the furnace. (Figure 48)

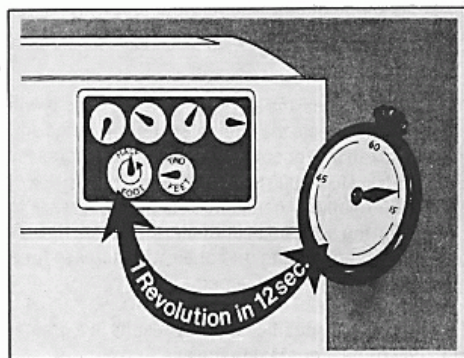


Figure 48

Using the half foot dial, we determine it takes 12 seconds for one revolution. Referring to a gas input table convert these figures to cubic feet per hour. (Figure 49) The table indicates that if one half cubic foot of gas is consumed in 12 seconds, the gas input to the furnace is 150 cubic feet per hour. To calculate the heating input, use the formula:

$$\frac{\text{heating input rate}}{(\text{Btu/hr})} = \frac{\text{Gas Flow Rate}}{(\text{cuft/hr})} \times \frac{\text{Gas Heating Value}}{\text{Btu/cuft}}$$

GAS INPUT				
SECONDS FOR ONE REVOLUTION	CUBIC FEET PER HOUR			
	ONE-HALF CU. FT.	ONE CU. FT.	TWO CU. FT.	FIVE CU. FT.
10	180	360	270	1,030
11	164	327	655	1,636
12	150	300	600	1,500
13	137	277	565	1,375
14	126	252	540	1,260
15	116	230	515	1,160
16	107	210	495	1,070
17	99	190	475	990
18	92	180	455	920
19	85	170	435	860
20	79	160	415	800
21	73	150	395	750
22	68	140	375	700
23	63	130	355	650
24	58	120	335	600
25	54	110	315	550
26	50	100	295	500
27	46	90	275	450
28	42	80	255	400
29	38	70	235	350
30	35	60	215	300
31	32	50	195	250
32	29	40	175	200
33	26	30	155	150
34	23	20	135	100
35	20	10	115	50
36	17	5	95	0
37	14	0	75	0
38	11	0	55	0
39	8	0	35	0
40	5	0	15	0
41	2	0	0	0
42	0	0	0	0
43	0	0	0	0
44	0	0	0	0
45	0	0	0	0
46	0	0	0	0
47	0	0	0	0
48	0	0	0	0
49	0	0	0	0
50	0	0	0	0

Figure 49

The heating value of the gas is how many Btu's you get for each one cubic foot burned. This can be obtained from the local gas company. In our example of natural gas, let's say that the heating value of the gas is 1,050 Btu's per cubic foot. The heating input is 150 cubic feet per hour times the heating value of 1,050 Btu's per cubic foot which equals 157,500 Btu's per hour.

If an oil furnace is used, calculate the heating input by multiplying the nozzle rating in gallons per hour times the oil heating value.

Because the fossil fuel furnaces are not 100% efficient, we must correct the input rate. Not all of this heat goes into the condition space, some will go up the flue. The difference is the efficiency. An efficiency test is performed by checking the CO₂ level of the flue products. You must then measure the difference between the flue gas and combustion air inlet temperature, and apply the data to a chart published by the American Gas Association. Combustion efficiency slide calculators are also available for this purpose. The formula used to calculate the air flow across the heat exchangers is as follows:

$$\text{CFM} = \frac{\text{Btu/hr. Input} \times \text{Combustion Efficiency}}{1.08 \times \text{Temperature Rise}}$$

In our example the numbers might look like this:

$$\text{CFM} = \frac{157,500 \times 0.75}{1.08 \times 50} = 2,188 \text{ CFM}$$

OUTSIDE AIR CALCULATIONS

Certain applications of air measurement pose substantial problems. For example, how would you measure the quantity of outside air introduced to a conditioned space for an economizer cycle. This information would be necessary in order to set the percentage of outside air for the preset ventilation

position of the air damper. Physical measurements of the quantities of air involved are difficult to measure and are usually inaccurate.

To calculate the percentage of outside air, make a ratio of the temperatures of the mixing air quantities involved. Use the following formula:

$$\% \text{ Outside Air} = \frac{\text{Mixed Air Temperature} - \text{Return Air Temperature}}{\text{Outdoor Air Temperature} - \text{Return Air Temperature}}$$

The mixed air temperature is taken at a point where there is good mixing of outdoor and return air. This usually occurs after the filter section. The outdoor temperature is measured under the outside air intake hood in a shaded area to reduce the effects of radiant heat from the sun. The return air temperature is taken in the return air duct.

For example, if the outdoor temperature was 100°F with a return air temperature of 75°F and a mixed air temperature of 85°F was measured, the percentage of outside air would be determined as follows:

$$\% \text{ Outside Air} = \frac{85^{\circ}\text{F} - 75^{\circ}\text{F}}{100^{\circ}\text{F} - 75^{\circ}\text{F}} = \frac{10}{25} = 0.40 \text{ or } 40\% \text{ Outside Air}$$

So far we have discussed air pressure theory in a duct system and methods of air flow determination by the use of pitot tubes and manometers, total external static pressure, static pressure drop across the evaporator coil, rotating and deflecting vane anemometers, hot wire anemometers and temperature rise methods for electric and fossil fuel heating systems. There are other methods that can be utilized, but these are some of the more common methods used in the field. Let's take a moment to discuss what happens at higher elevations.

EFFECT OF ALTITUDE ON AIR DISTRIBUTION SYSTEMS

It is important to note that air conditioning systems ratings and performance are based on conditions of standard air at sea level. Standard air is dry air at a barometer pressure of 29.92 inches of mercury, a specific density of .075 pounds per cubic foot, a specific volume of 13.33 cubic foot per pound, a specific heat of .24 Btu/lb/°F and at a temperature of 70°F. Air conditioning systems ratings and performance is based on 400 cfm/ton for straight cooling machines and 450 cfm/ton for heat pumps. So a four ton cooling system should have approximately 1,600 cfm for proper equipment performance and reliability. A five ton heat pump should move approximately 2,250 cfm of air.

At greater altitudes, the air properties and density will change. This affects the equipment performance and must be taken into account. As the altitude increases from sea level to 10,000 feet, the thermal properties of air remain relatively constant. It is not necessary to correct for the specific heat of air. At increasing altitudes, the specific humidity of air will increase for a given dry and wet bulb temperature.

This increase in specific humidity results in a greater enthalpy or heat content in the air.

At higher altitudes the specific volume of the air will increase due to lower atmospheric pressures, therefore the specific density becomes less. This brings us to the area of air flow. The air that passes through a condenser or evaporator will remain at a constant volume or cfm, but the density or weight of the air becomes less. A greater volume or cfm of air must be circulated at higher altitudes to achieve the same capacity ratings for the equipment as at sea level. System capacity is based on the mass flow rate of air or in other words, the pounds per hour of air circulated and the enthalpy difference per pound of air. The density of air at higher altitudes varies with its absolute pressure. To maintain the same mass flow rate (pounds per hour) at higher altitudes as at sea level, the air flow rate (cfm) must be increased at a rate inversely proportional to the air density ratio. If the air volume (cfm) is held constant and not increased at higher altitudes, the mass flow rate decreases at a rate directly proportional to the air density ratio. The air density is a ratio of the:

$$\frac{\text{Actual Air Density}}{\text{Standard Air Density}}$$

For example: Dry Air, Sea Level, 70°F has a density of .075 pound per cubic foot.

Using a 5,000 feet psychrometric chart the air now has a density of .0625 pound per cubic foot.

The air density ratio would be:

$$\frac{0.0625}{0.075} = 0.833$$

If the air flow rated for a system was 2,000 cfm at sea level, to achieve the same capacity or mass flow rate, the cfm must be increased as follows:

$$\text{CFM(Altitude)} = \frac{2,000 (\text{Sea Level CFM})}{0.833 (\text{Air Density Ratio})} = 2,400 \text{ CFM}$$

Figure 50 represents the air ratios at various altitudes.

ALTITUDE DENSITY FOR AIR			
ALTITUDE (ft)	AIR-DENSITY RATIO (at 70 F)	DENSITY (lb/ft ³ at 70 F)	SPECIFIC VOLUME (ft ³ /lb at 70 F)
0	1.000	.0750	13.33
500	.982	.0737	13.58
1000	.964	.0722	13.86
1500	.947	.0710	14.10
2000	.930	.0697	14.36
2500	.913	.0684	14.61
3000	.896	.0672	14.88
3500	.880	.0660	15.17
4000	.864	.0648	15.45
4500	.848	.0635	15.76
5000	.83	.0625	16.00
5500	.817	.0613	16.32
6000	.801	.0601	16.66
6500	.786	.0590	16.98
7000	.772	.0579	17.28
7500	.757	.0567	17.66
8000	.743	.0557	17.95
8500	.729	.0545	18.38
9000	.715	.0536	18.69
9500	.701	.0526	19.05
10000	.687	.0515	19.45

Figure 50

Lack of air flow results in poor system performance and lower equipment life. To ensure equipment reliability, a technician must be able to recognize and solve low air flow problems. This is accomplished by a thorough knowledge of air properties and measurement. Hopefully, this text has helped you understand how to perform various methods of air measurement.

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