System performance verification

Maximizing energy efficiency in heating and cooling

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esco press
Mount Prospect, IL
www.escogroup.org

PRINTING SECTOR UNION CWA LABEL CHICAGO, IL

ESCO Press
PO Box 521
Mount Prospect Il 60056
Phone: 800-726-9696
Fax: 800-546-3726
Website: www.escogroup.org

ISBN 1-930044-31-3

Printed in the United States of America

7 6 5 4 3 2 1

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Preface

The world around us is evolving and the drive to reduce energy consumption is stronger than ever. The increasing demand on dwindling resources has challenged us to find ways of further reducing overall energy consumption.

HVAC systems constitute forty to sixty percent of the total energy consumption in buildings within the United States. Efficiency ratings such as the Seasonal Energy Efficiency Rating (SEER), Energy Efficiency Rating (EER), Coefficient of Performance (COP) and Annual Fuel Utilization Efficiency (AFUE) have been established to aid the public in identifying the efficiency of new equipment. These ratings allow consumers to accurately compare HVAC systems prior to purchase. These ratings are also used by technicians to determine whether equipment meets or exceeds their stated energy ratings. The majority of older existing homes and structures have less efficient systems in operation that use more power than today's high efficiency systems.

Many factors can lead to a system operating less efficiently than its designed specification. Improper installation, service and maintenance of both new and existing systems, and changes to both indoor and outdoor conditions may lead to systems operating less efficiently than their original designed specifications.

The *System Performance Verification* training and certification series is not intended to be a comprehensive guide to **all** system performance issues; it was developed to aide technicians in many proper techniques and procedures used to both verify and optimize performance of HVAC systems with specific emphasis placed on:

- proper refrigerant charging procedures and net capacity verification
- psychrometric fundamentals
- combustion efficiency
- system airflow testing processes.

Introduction

The air surrounding us can be measured, filtered, circulated, cooled, heated, de-humidified, and humidified; but first, HVAC professionals should understand it.

Airflow is one of the most over-looked functions of heating and cooling systems. Without proper airflow, system efficiency is compromised. A technician cannot properly charge an air conditioning system using the system superheat or subcooling methods when there is improper airflow. A heating system without proper airflow may operate at an unsafe temperature or short cycle, reducing the efficiency and life of the furnace.

The quantity of air flowing across the evaporator changes the sensible heat ratio of the air conditioning system, in turn changing the amount of moisture the system can remove. Nominal airflow for a central air conditioning system is 400 cubic feet per minute (CFM). Depending on ambient air conditions for a location, the quantity of air required across the evaporator for moisture removal could be as low as 325 CFM per ton. The airflow may be high as 450 CFM for environments with low humidity.

System efficiency, air filtering, sound levels, and most important of all, human comfort, are all influenced by system airflow.

Properties of Air

To understand air we must understand air properties. The properties of air are constantly changing with any change in temperature, humidity level, or altitude.

Common properties of air are normally listed at sea level conditions, 1 atmosphere of barometric pressure and 68°F. The following are two air properties used in general calculations made by HVAC technicians:

Density = 0.075 lbs. per cu. Ft.
Specific heat = 0.24 Btu

Using these two properties of air (density, specific heat) and time, we can derive a factor used to calculate airflow. The factor, Btuh, and temperature difference are used to calculate the airflow volume required for heating or cooling.

This is a sensible heat factor used to calculate the volume of air based on the Btuh heating or cooling required for each room or the total Btuh for the structure. A room-by-room load calculation is the only acceptable method for determining required airflow for heating and cooling.

The Sensible Heat Factor of Air

Specific heat (0.24 Btu) × **Density** (0.075 lbs. per cu. Ft.) × **60 minutes per hour**
= a factor of 1.08

$$0.24 \times 0.075 \times 60 = 1.08$$

When determining the air quantity, there are two factors used: Volume, measured in Cubic Feet per Minute (CFM), and Velocity, measured in Feet Per Minute (FPM). Not only is it important to have the proper quantity of air, but the air must also flow at the proper speed to reduce unwanted noise or drafts.

Based on nominal airflow of 400 CFM per ton, an air conditioning system will move a few tons of air. At standard conditions, air weighs 0.075 pounds per cubic foot. A three-ton air conditioning system, moving 400 CFM per ton, will have 1,200 CFM of air flowing through the system. 1,200 CFM multiplied by 0.075 lbs. per cubic feet equals 90 lbs. delivered each minute. Ninety pounds multiplied by 60 minutes equal 5,400 pounds of air per hour.

5,400 pounds of air/hour multiplied by 12 hours of blower run time equals 64,800 pounds.
64,800 pounds divided by 2,000 pounds per ton equals 32.4 tons of air moved by a ⅛ to ¼ hp blower.

Airflow Measuring Tools

There are many types of instruments that use various methods of measuring air, such as fluid pressure, electrical resistance, electrical current, electrical voltage, and mechanical motion. With most instruments, the speed of the flowing air is measured.

If the size of the opening and velocity of the air is known, the volume of airflow can be determined.

The actual CFM must be calculated manually using the velocity and area of the air delivery opening. Some instruments can display the actual CFM measurement if the area of the opening for the air delivery device is programmed into the instrument.

Measuring Airflow

Air measuring instruments are not the only means to measure airflow. System airflow can also be calculated by using the heating or cooling equipment operating characteristics. Blowers are designed

Various airflow measuring tools from left to right: Anemometer, Flow Capture Hood, Velometer and Magnehelic Gauge.

to move a certain quantity of air based on the size of the blower wheel, horsepower of the motor, and friction from the components that make up the system. The amount of work required by the blower depends on the capacity of the system, the supply and return ducts, types of air filters, and components in the airflow path.

The resistance to air movement creates a pressure drop across the blower assembly. This very low pressure is measured in inches of water column. A "U" tube manometer will support a column of water 27.7 inches high for each pound of pressure.

With both ports open and one connected to a pressure other then atmospheric, the fluid level falls on one side and rises on the other. The measured pressure is the sum of the total distance between the fluid on each side. In this example .1 + .1 = .2 Inches WC.

Common Pressures and Equivalents

1 pound per square inch (PSI) = 27.7 Inches of Water Column ("WC)

27.7 "WC = 6894.76 Pascals (PA)

1" WC = 249 PA

.1 "WC = 24.9 PA

.01 " WC = 2.49 PA

1 PA = .004 "WC

There are two pressures the blower must overcome: static and velocity pressure. Static pressure pushing in all directions is measured as a positive pressure in a supply duct and a negative pressure in the return duct. Velocity pressure is the pressure created from the movement of the air.

Blower Performance Chart

Most manufacturers provide performance charts that indicate the volume of air the blower can supply based on the motor horsepower, blower wheel revolutions per minute (RPM), and system static pressure. Not all blower performance charts indicate the CFM under the same conditions.

For example, special consideration must be given to whether or not the chart is based on a wet or dry evaporator coil. A furnace may have two performance charts: one for the furnace without additional components, and one indicating the CFM with additional components such as an evaporator coil. By measuring the static pressure and using the blower performance chart for the equipment, the total volume of air can be estimated. If there is an evaporator coil in the system, this method is only accurate with a clean or like new coil.

Before a duct system can be designed, the available static pressure from the blower performance must be known. The available static pressure for most residential furnaces and air handlers is a maximum of 0.5 inches water column (WC).

Model	Speed	Volts		E.S.P (In. of H_2O)							
				0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
GPC1336M41* GPC1336M43*	LOW	230	CFM	1122	1078	1032	972	915	804	687	558
			WATTS	338	330	321	310	300	283	264	250
	MED	230	CFM	1387	1331	1264	1209	1119	1041	935	748
			WATTS	456	440	428	412	399	382	363	330
	HIGH	230	CFM	1521	1454	1388	1311	1230	1144	1055	939
			WATTS	534	521	510	490	477	461	442	420
GPC1348M41* GPC1348M43*	T1 (G)	230	CFM	1,140	1,395	1,360	1,310	1,265	1,235	1,190	1,130
			WATTS	275	285	295	315	325	335	345	355
	T2 / T3	230	CFM	1,795	1,765	1,715	1,695	1,650	1,600	1,500	1,375
			WATTS	475	490	505	520	530	535	510	475
	T4 / T5	230	CFM	1,860	1,820	1,785	1,745	1,700	1,625	1,515	1,395
			WATTS	515	530	545	565	570	550	535	485
GPC1360M41* GPC1360M43*	T1 (G)	230	CFM	1,755	1,720	1,685	1,645	1,615	1,570	1,530	1,465
			WATTS	420	435	455	460	475	490	500	500
	T2 / T3	230	CFM	1,850	1,820	1,775	1,735	1,705	1,675	1,610	1,495
			WATTS	480	500	515	525	535	555	545	520
	T4 / T5	230	CFM	2,180	2,125	2,050	1,975	1,875	1,800	1,655	1,530
			WATTS	770	755	725	700	675	640	575	540

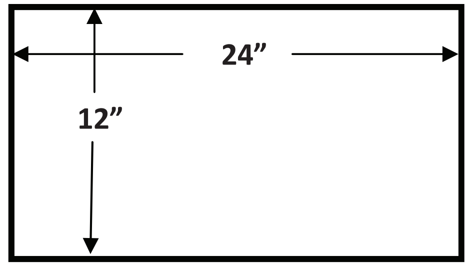
If the blower performance chart indicates that the blower can deliver the required CFM at 0.4"WC, the total pressure drop for the supply grilles, air filter, return grilles, supply duct, return duct, evaporator, and any accessories on the air side must not exceed 0.4"WC.

The normal Permanent Split-Capacitor (PSC) blower motor has a limit to the amount of force and speed that can be provided to the blower wheel. A blower with an Electronically Commutated Motor (ECM) operates by varying the speed of the motor to move the required amount of air. ECM motors can operate at a slightly higher static pressure compared to PSC motors of the same horsepower. The correct CFM settings can be made by setting a dipswitch or connecting the proper wiretap, which determines the RPM of the motor. A PSC motor uses less power as resistance to airflow increases. While the opposite is true of the ECM motor, power usage will increase from increased resistance to airflow. The ECM motor power usage will increase from increased resistance to airflow. The ECM motor provides flexibility in design, but should not be used with the intention of fixing a design problem. A system with a design problem must be fixed in order for the system to function properly and efficiently.

Note: Always read the notes that accompany a blower performance chart. The data shown may not include deductions for other components and accessories such as a wet coil, filter, heating elements, etc.

Most airflow meters measure the velocity of airflow. The actual CFM has to be calculated based on the area of the duct or grille in square feet and the velocity of the air. Free area in square feet times the velocity equals CFM.

CFM = square feet × FPM
12" x 24" = 288 Sq. In.
288 Sq in ÷ 144 sq in. = 2 sq. ft.
CFM = 2sq. ft. x 225 FPM
CFM = 450



For example, if the duct opening has a measurement of 12 inches by 24 inches and an area of two square feet, and the air has a velocity of 225 FPM, 450 CFM of air will be exiting the duct.

The velocity of the air in the duct will vary from zero in the boundary layer at the duct wall to a maximum velocity near the duct centerline. For this reason, a number of readings must be taken and averaged. The method of establishing basic equal points for measurements is called taking a traverse. Whether the duct is square, rectangular, or round, two holes are made in the duct to make the traverse. One hole is drilled in the top or bottom and the other in the side.

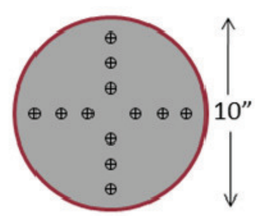
Approximately 24 measurements should be taken for a 10-inch by 20-inch duct.

Remember to convert the square inches of the duct to square feet by dividing the square inches by 144. The speed or velocity the air is moving in FPM times the square feet of the duct interior size equals the CFM.

A round duct requires two holes for the measurements. One hole at the bottom or top and one on either side. For a 10-inch round duct, approximately twelve measurements are required.

To find the area for a round duct, use the formula: Area = $\pi \times R^2$.
*(**Remember:** π is equal to 3.14)*

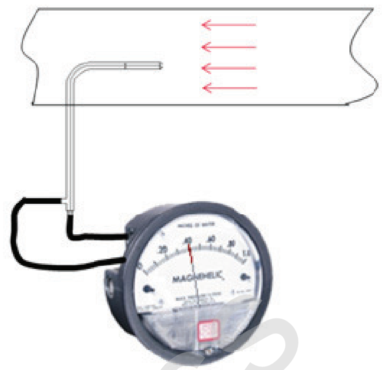
The area for a 10-inch duct is:
Area in sq. ft.= (π x R2) ÷ 144
Area in sq. ft. = (3.14 x 5^2) ÷ 144
Area in sq. ft. = (3.14 x 25) ÷ 144
Area in sq. ft. = 78.5 ÷ 144
Area in sq. ft. =.545



Measuring Airflow Using a Pitot Tool Traverse

The method of establishing basic equal points for measurements is called taking a traverse. Whether the duct is square, rectangular, or round, two holes are made in the duct to make the traverse. One hole is drilled in the top or bottom and the other in the side. A pitot tool is used to measure the velocity pressure. When using this method, remember the following:

- It is important to get an equal number of readings covering the whole cross section of the duct.
- The traverse must be made at a location at least five duct diameters downstream from elbows or constrictions in the ductwork.



- Measure with the pitot tube facing into the airstream.

Approximately twenty-four measurements should be taken for a 10-inch by 20-inch duct and twelve measurements for a 10-inch round duct .

When measuring with a pitot tool, the velocity pressure must be converted to velocity in feet per minute. Multiply the square root of the velocity pressure by a factor of 4004.4 to convert to feet per minute (FPM).

The following points should be adhered to:

- Make an equal number of readings covering the whole cross section of the duct.
- Make the traverse in a location at least five duct diameters downstream from elbows or constrictions in the ductwork.
- Measure with the pitot tube facing into the airstream.
- Average the velocity readings covering the whole cross section of the duct.
- Apply the formula: CFM = FPM x Square feet

Example:
Twelve Velocity Pressure measurements are obtained for an 8-inch round duct.
.0244 + 0.0345 + 0.0225 + 0.0122 + 0.0256 + 0.0233 +0.0245 + 0.0320 + 0.0252 + 0.0344 + 0.0186 + 0.02 = .3072 ÷ 12 =.0256” w.c.

Average Velocity Pressure: .0256
Velocity = $4000.4 \times \sqrt{.0256}$
Velocity = $4000.4 \times .16$
Velocity = 640 FPM

Area in square feet for 8-inch round πr^2 duct = ÷ 144
Area $3.14 \times 4^2 =$ ÷ 144
Area $3.14 \times 16 =$ ÷ 144
Area 50.3 = ÷ 144
Area = .35 square feet
Now calculate the CFM:
CFM = .35 sq. ft. × 640 FPM
CFM = 224

Airflow – Supply Grille/Diffuser

The net free area must be known when measuring the airflow delivered through a grille or diffuser. The net free area or AK factor (area in square feet) must be estimated for grilles without manufacturer-published specifications. In addition, the net free area or AK factor may not be a constant. The change in CFM will not always be proportional to the change in air velocity; it depends on the design of the grille. The net free area for a stamped metal grille can be as low as 70 percent of the total area of the grille. If the grille is delivering the amount of air based on the manufacturer’s design parameters, a free area of 70 to 75 percent of the total area may be used.