NADCA White Paper: Restoring Energy Efficiency Through HVAC Air Distribution System Cleaning

Contributors:
Mike White, Chairman, Education Committee, Dan Stradford, Chairman, White Paper Subcommittee, Bob Baker, ASHRAE, Anne Marie Blankenship, Southern California Edison, Charlie Cochrane, NADCA, Mike Dexter, NADCA, Scott Gordon, NEBB, Tony Hill, NADCA, Julia Luongo, University of Colorado, Long Nguyen, Southern California Edison, Robert Rizen, NADCA, April Yungen, NADCA

Introduction

As the industry's leading global advocate and trusted resource for reliable information, the National Air Duct Cleaners Association (NADCA) is uniquely qualified to provide guidance for consumers and the industry on the best practices for inspecting, maintaining and restoring HVAC systems.

One of the critical aspects of HVAC systems is energy consumption and the roles that HVAC engineering, construction, and maintenance play in optimizing energy usage.

This paper covers the specific topics of:

A. How cleaning reduces HVAC energy consumption.
B. How energy consumption can be calculated with pre-cleaning and post-cleaning measurements.
C. Mechanical and other issues within HVAC systems that contractors encounter while inspecting and/or cleaning that can be reported and corrected to maximize HVAC energy efficiency.

IMPORTANT NOTE: Much remains to be learned about measuring and improving energy efficiency through HVAC air distribution system cleaning. This paper, therefore, will remain a work in progress until the methods described herein have been fully tested in field trials.

Disclaimer

Although the following information reflects current methods for energy monitoring in the cleaning of HVAC systems, readers should recognize that new developments regularly occur and should familiarize themselves with the most current information when determining the appropriate steps to take.

Revised - November 2016

NADCA recognizes that differences in opinion exist as to how to measure and interpret energy use in HVAC systems. We have endeavored in this paper to find consensus among a broad spectrum of representatives in the HVAC cleaning industry, test and balance industry, and energy efficiency field.

This document was written in the United States of America and is intended primarily for use in that country. This material may also prove useful for industry professionals and others operating outside the USA. All users of this document are encouraged to refer to applicable federal, state/provincial, and local authorities having jurisdiction over the subjects addressed within this document.

Condenser Coil Cleaning

Although not part of the air distribution system, condensers reject (remove) heat from the refrigerant of an HVAC system, typically through coils similar in appearance to evaporative coils. Particulate and other buildup on the surface has a similar insulating effect. Because condensers are outside the airstream, they typically are not part of the cleaning process per the NADCA ACR Standard.

However, cleaning condensers can have a significant, sometimes dramatic, positive impact on energy efficiency, and periodic cleaning of condensers and condenser coils is a necessary part of HVAC maintenance.

Since the methods for cleaning condensers are similar to those of cleaning evaporator coils, cleaning condensers should be strongly considered as an add-on option to HVAC air distribution cleaning to restore greater energy performance.

How HVAC Air Distribution System Cleaning Restores Energy Performance

Energy is consumed by HVAC systems through a number of processes. Air is typically distributed through the ductwork via an electrically-powered fan. Cooling coils remove heat from the air. Heating coils add heat to the air.

Through normal HVAC usage, particulate in the air slowly collects on the surfaces of various HVAC components, resulting in a gradual loss of energy efficiency. Some loss of efficiency via a single dirty component may be minor. When the loss through each component is added up, however, the impact could be considerable. Generally, the greater the buildup, the greater the energy loss.

Removal of the buildup of particulate on HVAC components restores energy performance to the system.

The following components in the airstream, when cleaned, are common sources of restored energy performance.

Evaporator Coil: Air is typically cooled in an HVAC system by passing through an evaporator coil. Particulate and other material buildup over time has an insulating effect on the surface of the coil, leading to longer cooling times and greater energy consumption. Additionally, buildup between the fins of the coil increasingly restricts airflow over time. The evaporative coil cleaning process is described in the NADCA ACR (Assessment, Cleaning, and Restoration) Standard.

Heating Coil: Similar to a cooling coil, the heating coil in the furnace plenum is composed of hundreds of narrow air passages. Any restriction in these passages reduces airflow and diminishes effectiveness of the heating. The most frequent cause of a restricted coil is an accumulation of dust, dirt, or other fouling agents. Often a consequence of neglecting maintenance such as regular filter changes, dust and dirt may plug small coil passages and reduce downstream airflow. This degrades the effectiveness of heating throughout the conditioned space. It also increases heating costs as the furnace must run longer to meet thermostat settings. A severely obstructed coil may restrict airflow to the point that the system overheats, tripping a safety high-temperature switch and automatically shutting down the furnace. The heating coil cleaning process is described in the NADCA ACR Standard.

Reheat Coil: A reheat coil is used in some HVAC systems and looks similar in appearance to an evaporative coil. It is typically positioned near the terminal end of the duct system and acts as a secondary heat source to “reheat” air from the HVAC unit. Reheat coils are used for humidity control and/or occupant comfort. VAV boxes commonly include reheat coils. Because the spaces between the fins can be quite narrow, they can act almost as a filter, filling with particulate over time. Periodic inspection and cleaning of the coil are needed to ensure proper heating capacity and air distribution in the occupied space.

Turning Vanes: Turning vanes divert air around corners in duct systems to direct airflow. Particle collection can narrow the spaces between vanes, but more importantly, large debris blowing through the duct can get caught on vanes and create significant blockage to airflow. Filters, cardboard, pieces of separated insulation, delaminated insulation, rags and other materials are sometimes found and removed from turning vanes in the cleaning process.

Supply Air Outlet (Register): Located at the end of the supply ductwork, supply registers provide air to the occupied space through a series of blades which are normally adjustable for directional distribution or diffusion. When dirt and debris build up on the register and its blades, airflow can be seriously reduced, negatively impacting energy performance and comfort in the occupied space.

Return Air Inlet (Register): Air flows into return registers from the occupied space to the HVAC unit through ductwork, or in some cases, via an open plenum such as a ceiling plenum. This type of register can get very dirty due to dirt and dust from the occupied space, narrowing the passageway for return air and restricting air movement. Over time it can become completely clogged. Buildup on return registers can result in a system that is severely strained and inefficient.

Fresh Air Intake Screen (Outside Air Screen): Fresh air intake openings in HVAC systems are integral to the quality of the air inside a building. Local codes dictate the amount of fresh air that is required for the health and safety of building occupants. Often a screen or mesh is placed over the fresh air opening to prevent birds, rodents and debris from gaining access into the opening. These screens become plugged by debris in the environment getting caught on the screen or mesh. Screens may also get damp from rain or humidity which causes debris to become “glued” to the screen or mesh. This debris inhibits the proper fresh airflow into the building, which leads to improper pressure relationships within the building and can cause excess buildup of carbon dioxide within the facility.

Fan (Blower): Fans, also known as blowers, move air across the evaporator coil for cooling and the heat exchanger for heating. This is achieved by rotating a series of blades, which are connected to a shaft and driven by a motor. These blades are designed to move a certain volume of air, and particulate buildup on the fan blades, particularly curved ones, reduces the capacity of the blades to move air causing the blower motor to run longer while pushing less air per rotation.

Damper: A damper is a valve or plate that stops or regulates the flow of air inside a duct, chimney, VAV box, air handler, or other air-handling equipment. Dampers are used to balance and/or control airflows. There are three types: single-blade, opposed-blade and parallel-blade. Single-blade volume dampers are in branch ducts, typically at the connections to main ducts. Opposed-blade dampers are in supply air outlets and are characterized by pairs of damper blades that move in opposite directions. Parallel-blade dampers are used primarily for mixing air streams. The blades are positioned to operate parallel to one another and direct the airstreams for the maximum mixing effect. The result of excessively dirty dampers is restriction of airflow. Also heavy particle buildup may restrict the movement of the damper blades, resulting in restricted airflow and possible increased back pressure on the system and compressor. This leads to fans and compressors working harder, increasing energy consumption and reducing equipment longevity.

Sound Attenuator: Sound attenuators use sound-absorbing fibrous material with perforated sheet metal facings that allow sound energy to pass through and be absorbed by the fibrous fill. This reduces noise emanating from an HVAC system. Also called duct silencers, they sit in the airstream and restrict the airflow through a system of interior baffles. When sound attenuators become dirty or impacted, the amount of air delivered through the duct system is reduced. Depending on the level of restriction, this affects airflow, temperature, and comfort level.

Duct Liner: Internal insulation, also called duct liner, has been used for many years inside ductwork, mixing boxes, linear diffusers, air handlers and many other HVAC components. Fiberglass insulation is most common but other materials may be used as well. The Sheet Metal and Air Conditioning Contractors National Association (SMACNA), which is the industry authority for sheet metal duct construction, has specific installation guidelines for duct liner which, if not followed, can lead to insulation separating from the ductwork. Separated insulation will reduce airflow and loose insulation can blow downstream and land on surfaces such as reheat coils, supply air outlets and volume dampers just to name a few.

Older duct liner may be well bonded to the duct wall but begin to delaminate, shedding pieces of insulation downstream. A careful inspection of any HVAC system will determine if and where any failed or failing internal insulation may be found. Removal of internal insulation will impact the size of the internal cross section of the duct or system component if replacement insulation is not specified. Failure to replace the removed insulation will alter the acoustic properties of the system and will impact thermal performance as well.

Air Straightener: Also known as a flow straightener or air blender, this device is used to straighten the airflow and reduce turbulence in HVAC systems. It is typically found in conjunction with duct sensors. The cross-section shapes of these "honeycombs" may be of square, circular or hexagonal cells. These straighteners can become clogged with dust and other debris and serve as an impaction point for failing duct insulation and other large debris that have come loose. This will restrict airflow and affect energy efficiency.

Airflow Measuring Station (AFMS): An AFMS is used in an HVAC system as a direct measurement device of the air volume which is circulating through the system. An AFMS could be part of an outdoor air intake louver assembly which measures the volume of outside air introduced into an HVAC system. As airflow varies on a variable air volume (VAV) system, the AFMS controls the position of an outdoor air damper which modulates to maintain the proper volume of outdoor air into the air handling unit (AHU).

There are two main types of AFMS: Differential pressure types that use either a pitot tube array (pronounced pē-tō – described later in this document) or flow ring assembly which measures the velocity pressure of the air and, secondly, a thermal dispersion type sensor which employs a small heater that is used in a mathematical calculation of airflow.

Proper maintenance is required on both types, however the differential pressure type AFMS is prone to calibration issues if the pitot tubes and air lines become clogged. Airflow calculations will be in error if the lines and pitot tubes become clogged with dirt, causing improper control of ventilation (outdoor) air. Excessive ventilation air imposes an unnecessary energy penalty to an HVAC system.

Velocity Sensors/Controllers: Velocity sensors/controllers are used in variable air volume (VAV) terminal boxes to measure airflow that is supplied to a conditioned space. Airflow is controlled over a range of maximum and minimum settings. Additionally, zone heating is often controlled based upon the measured air volume. Velocity controllers operate similarly to the differential pressure type AFMS described in the previous section.

If velocity sensors become clogged with dirt, inaccurate readings will occur, which can cause problems ranging from comfort complaints to increased energy consumption. When the zone temperature is not satisfied, the VAV box damper will open wider, increasing the air handler fan speed and associated brake horsepower (the actual power applied to a motor).

Mist Eliminators: Mist eliminators are designed to eliminate water droplets from the HVAC air stream by collecting them on a surface. These water droplets are then diverted to the drain line system. As particulate builds inside, the eliminator loses its ability to properly remove moisture and reduces airflow through the system. This causes an increase in back pressure and forces the system to use more energy to compensate.

Humidifiers: A humidifier adds water vapor to the air to increase humidity. When installed in an HVAC system, the humidifier or a section of it will be in the air stream and will cause some resistance to air passing by it. Over time, particulate will collect on the humidifier, creating greater resistance to the airflow.

Mixing Box: Mixing boxes are designed to blend air from different sources to achieve the desired air temperature in the space it serves. These boxes typically are comprised of an internally-insulated sheet metal plenum box, a volume damper, one outlet and two inlets. They are usually found at the downstream or near terminal end of the system and may be referred to as terminal mixing boxes. Mixing boxes are sometimes equipped with fans and cooling or heating coils. The box itself doesn't tend to degrade or get dirty unless the insulation is failing. The internal components can accumulate dust and debris, restricting airflow.

VAV Box: VAV, or variable air volume, boxes control the temperature of the supply air by varying the quantity of air. Each box serves a zone (group of rooms or specific area) through the action of a thermostat located in this specified area. VAV boxes have numerous parts, already covered above, that can collect dirt. A damper is located inside with a controller or actuator linked to it on the outside of the box. Some VAV boxes use a reheat coil to affect the temperature as needed. These boxes can have a screen before the coil and other parts in the air stream which can collect dust and dirt over time, restricting airflow and efficiency.

FPB or Fan-Powered Box: This is another type of VAV box. It functions the same as a VAV box, controlling the volume of air as needed to the occupied space, except it employs a fan to augment the volume of air. Dirt buildup on the fan blades and housing interior can reduce airflow in addition to the negative effects of buildup on the other parts of the fan-powered box as mentioned above.

Measuring Air Distribution System Performance, Before and After Cleaning

Important Note: The science and technology of <u>accurately</u> measuring energy consumption and air dynamics in HVAC systems is complex and requires extensive training. Many factors may be involved, particularly in larger systems. The methods described below offer a simplified approach to approximating HVAC performance before and after cleaning. These methods provide NADCA members and others a reasonably efficient way to determine and quantify improvements in energy efficiency. While useful and practical, they do not account for every factor. They are not intended to replace, and are not comparable to, the more thorough methods used by testing and balancing professionals, HVAC engineers, and others fully qualified in this field.

Proper cleaning of a dirty HVAC system will result in some degree of improved airflow and improved heat transfer in cleaned coils. Determining the percentage of improvement permits the cleaning contractor and system owner to weigh the cost and benefits of the cleaning and may help establish a cost/benefit ratio for periodic cleaning in the future.

Determining system performance requires knowing the cubic feet per minute (CFM) output and the temperature change before and after the coils. From this we can calculate the output of the system in BTUs or British Thermal Units (see definitions below).

For systems with fresh air intakes, an additional measurement of humidity is required before and after the coils. This is because outdoor air can increase or decrease humidity levels of indoor air and this can significantly impact temperature measurements and the total heat content of indoor air.

IMPORTANT NOTE ON FILTERS AND CFM: Filters, dirty or clean, restrict airflow. To ensure that a change in filters does not skew pre- and post-cleaning measurements, the filters must be in the same condition for both readings when measuring CFM before and after cleaning. That is, if the filters are new, used, or removed for the "before" CFM reading, they must be the same for the "after" reading.

Definitions

Sensible Heat: Heat sensed by a thermometer.

Latent Heat: The quantity of heat absorbed or released by a substance undergoing a change of state, such as ice changing to water or water to vapor, at constant temperature and pressure. Warming or cooling moisture in the air consumes some energy that does not register on a thermometer.

Total Heat: Sensible Heat plus Latent Heat.

BTUs (British Thermal Units): The amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit. As an example, one four-inch wooden kitchen match consumed completely generates approximately 1 BTU.

Delta: For our purposes, the variation or difference between two measurements or amounts, represented by the mathematical symbol Δ.

Delta T: The difference between two measurements of temperature, sometimes represented as Δt.

CFM (Cubic Feet per Minute): In air distribution systems, this is a common measurement of the volume of air passing a specific point or duct opening.

Delta H: (represented as Δh, also known as *enthalpy* – See definition below) For our purposes, the difference between two measurements of heat content of dry air, as expressed in BTU/lb. To determine the heat content of air, the level of humidity in the air, known as the relative humidity, must be measured and factored in. This relative humidity and temperature are then found on a psychrometric chart (see definition below) to determine Δh.

Dry Bulb Temperature (DB): The temperature of a gas or mixture of gases registered by an accurate thermometer. The dry bulb represents the measure of sensible heat or the intensity of heat.

Wet Bulb Temperature (WB): Originally, the temperature of the air when the bulb of the thermometer is covered by a wet cloth. Wet bulb temperature helps to measure relative humidity and is now commonly measured with electronic instruments.

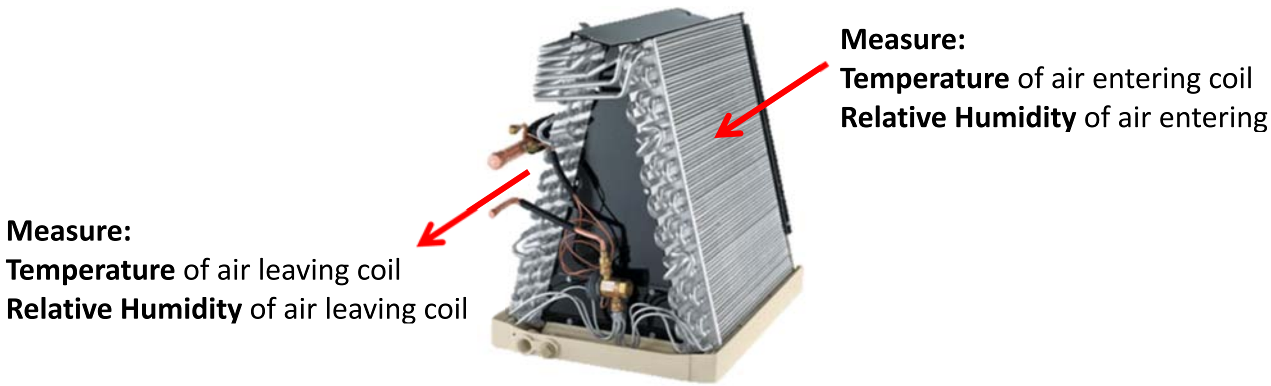
Enthalpy: The total quantity of heat energy contained in a substance, also called total heat; the sum of the sensible heat and latent heat in an exchange process. In the HVAC industry, measurement is in BTU/lb of dry air.

Psychrometric Chart: A chart that shows, among other things, total heat, computed from temperature and relative humidity.

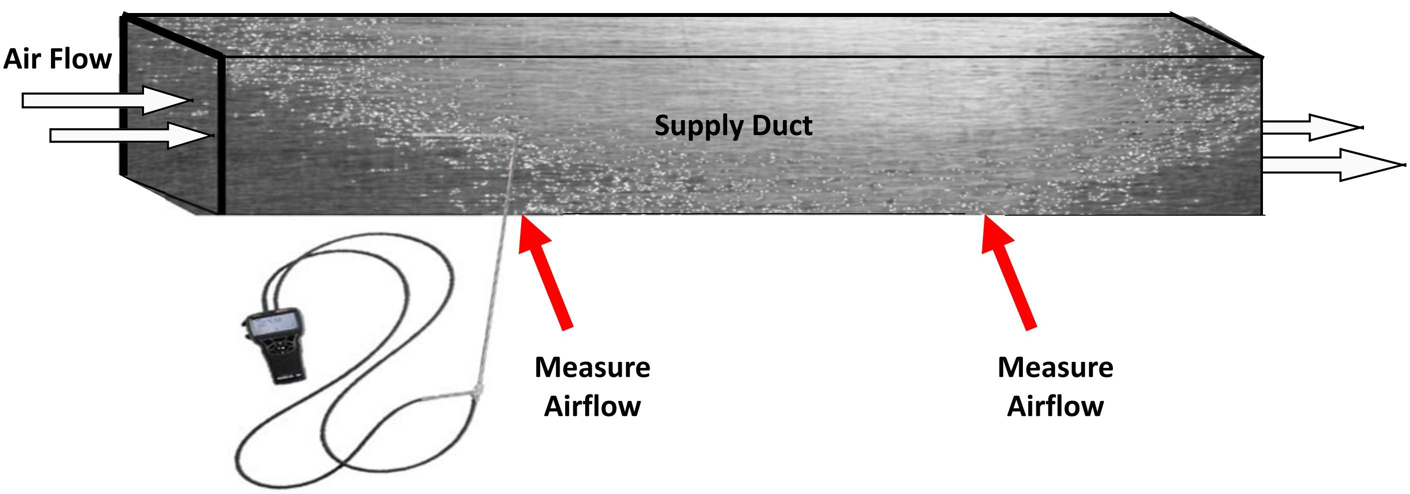
Where Measurements are Taken

Temperature **of the air is measured entering and leaving the evaporator coil.**

Relative humidity **of the air is measured entering and leaving the evaporator coil.**



Air pressure **is measured at the main supply duct with a pitot tube.**



Air velocity**, if needed, is measured at a return register. This also gives CFM.**

Formulas for Measuring BTU Output

Below are two different formulas for measuring HVAC performance.

These formulas provide a way to calculate BTUs consumed by the HVAC system before and after cleaning. For example, if BTUs are 10,000 before cleaning and 15,000 after, we have created a 50% improvement in capacity, which equates to greater energy performance.

FORMULA NO. 1:

The first formula is for systems with no fresh air intake, primarily residential systems. With no fresh air intake, there is little influence from outdoor humidity so we do not, in general, need to take humidity into account. Any factor that brings humidity inside, such as a leaky building, may increase humidity as a factor and impact the accuracy of this method.

In dry climates, outdoor air entering a structure can reduce indoor humidity. As stated earlier, this method will offer a reasonably accurate measurement of system performance in a simplified approach.

The instruments and methods for determining each step of the formula – temperature, CFM, etc. – are discussed afterward.

The formula is:

$$BTUs/hour = CFM \times \Delta T \times 1.08$$

Temperature (T) is the dry-bulb temperature of the air measured entering and leaving the evaporator coil (ΔT).

This formula provides the sensible heat load across the evaporator coil.

FORMULA NO. 2:

For systems with a fresh air intake, which includes most commercial systems, the formula is:

BTUs/hour = CFM x Δh x 4.5

This formula provides the total heat load (sensible + latent) across the evaporator coil.

In order to determine h (enthalpy), both the dry-bulb temperature and relative humidity (or, as an alternative, the wet bulb temperature) of the air entering and leaving the evaporator coil is required. The two measured points are then either plotted on a psychrometric chart, or entered into software such as Munters PsychroApp to determine the enthalpy of each air stream. The difference between the leaving air enthalpy from the entering air enthalpy is the Δ*h* of the two airstreams.

Equipment Required

FORMULA 1:

1. Electronic thermometer: A digital instrument that measures temperature.
2. Manometer: For our purposes, an instrument that measures air pressure.
3. Pitot tubes: (Pronounced pē-tō) Thin metal tubes that attach to the manometer and are inserted into the duct or air stream to measure air pressure. Tubes of 18”, 24”, and 36” should be available.
4. Rotating vane anemometer: An instrument with propeller-type fan blades (vanes) that are turned by air movement and measure air velocity in FPM.

FORMULA 2:

1. Electronic thermometer and hygrometer: A digital instrument that measures temperature and relative humidity (or, as an alternative, wet bulb temperature).
2. The same instrumentation as listed for Formula 1.

NOTE: All instruments should be calibrated as per manufacturer's specifications.

Taking Measurements

Before taking any measurements, the system should be on and running stably with the coils in operation. Some systems may achieve this in minutes and others, particularly larger commercial systems, may take an hour or two.

Evaporator Coil

The electronic thermometer and hygrometer is used, by drilling holes in the appropriate location in the AHU (air handling unit) cabinet or ductwork connected to the cabinet and inserting a probe, to take readings of the air entering and leaving the evaporator coil.

IMPORTANT NOTE: When drilling holes near a coil, care must be taken not to drill into the coil or any other device. Ensure there is adequate clearance before drilling.

1. Locate a spot in the sheet metal on the upstream side within six inches of the coil. This should be halfway up or across the coil where typical airflow and temperature can be expected. On larger coils or compartmented coils, select two or more locations as needed and use the average of the readings. If the readings differ markedly, take readings at further locations to ensure you are measuring similar temperatures.
2. Drill a hole in the spot(s). The hole should be just large enough – typically ¼" or 3/8" – to insert the hygrometer probe.
3. Note the readings for temperature and, if using Formula 2, relative humidity.
4. Remove the probe and seal the hole(s) with plastic plugs, foil tape, or an appropriate alternative. Repair any external insulation that may have been removed to facilitate obtaining the readings.
5. Repeat the same process on the downstream side within 6" of the coil.

Calculating Temperature Readings

For a single reading on each side of the coil, simply subtract the downstream temperature from the upstream temperature. The result is Delta T (ΔT).

Example: 70 degrees (upstream) minus 55 degrees (downstream) = 15 degrees = (ΔT).

For multiple readings on either side, add them up for each side and average them out.

Example: Upstream: 70 degrees plus 72 degrees plus 71 degrees = 213. Divide by 3 to get average: 213 ÷ 3 = 71. This is used as the upstream temperature.

For multiple readings, do the same as with temperature above. The same instrument is typically used to measure both air temperature and relative humidity.

Measuring CFM

Below are two methods of measuring CFM. The first is a basic method. The second is a more advanced, but more accurate method.

Other methods of measuring CFM may be used, such as a flow hood, as long as the same instrument is used the same way before and after cleaning.

Basic Method: Return Inlet or Supply Outlet Airflow

Rotating Vane Anemometer

There will be times when a simple method of measuring CFM is preferred, or a traverse measurement (see below) cannot be performed because a straight section of ductwork is not available in the main supply air duct. When this occurs, a less accurate method of estimating airflow can be used with an Electronic Rotating Vane Anemometer. This instrument provides a digital readout of the velocity which is automatically averaged for a fixed time period.

CFM is measured with an anemometer at a return register. If a return register is not available, such as in systems with no return duct, the CFM measurement can be done at a supply register. A return register going into a ceiling plenum may also be used.

Four CFM measurements will be taken at the register, in each of four quadrants – upper right, upper left, lower right and lower left. Use the average of these four measurements as your CFM reading.

A note on Ak factor: When using a Rotating Vane Anemometer, a correction factor, known as a "Ak" or "K" factor is required to determine actual CFM. The Ak factor is the percentage of CFM that goes through a register after accounting for the airflow resistance caused by the register itself. However, because we are doing *comparative* readings before and after cleaning and we are seeking to calculate only the *percentage of CFM increase*, for our purposes the Ak factor will NOT be factored into the calculation.

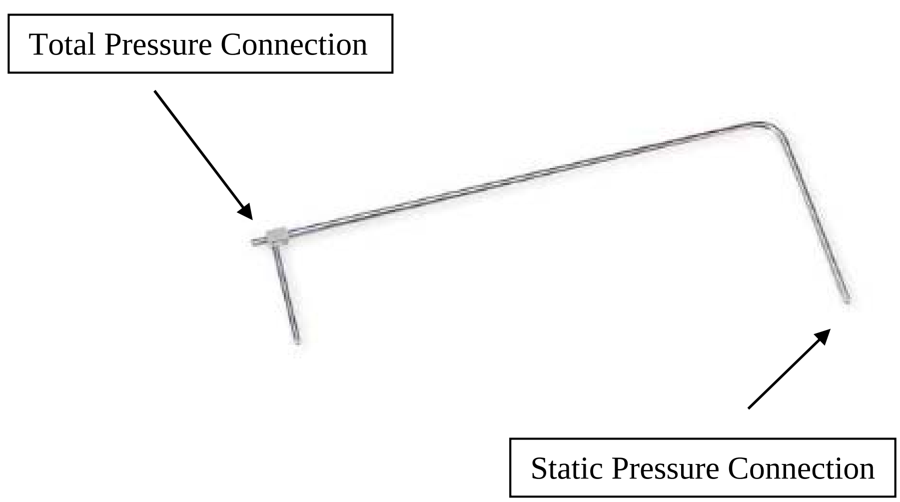
<u>Advanced: Main Supply Duct Airflow</u>

Traverse readings:

A duct traverse reading is the most accurate method of calculating airflow. The goal of a traverse is to accurately measure an equal area profile of the air velocity passing through a duct opening. The average velocity is then multiplied by the open area of the duct to determine CFM of airflow.

Digital Manometer

Pitot Tube



a. Find a straight section of supply duct that is located about 6 to 10 duct diameters downstream from the nearest fitting. Quite often, this much straight duct is not available. Therefore, you will have to use the best longest straight duct section available, possibly with some sacrifice in accuracy.
b. Measure the internal dimensions of the supply duct, allowing for internal duct liner. Multiply the width of the duct by the height of the duct to determine the area in square inches. Divide square inches by 144 to determine the area of the duct in square feet.
c. Based on the internal dimensions of the duct and using resources listed at the end of this document, or available apps, (such as TABcalcs), determine the proper location of the holes to drill in the ductwork. Drill the appropriate size hole (typically 7/16") to accommodate the pitot tube.
d. Mark the pitot tube as determined in step c above. Use electrical tape to mark the pitot tube.
e. Using an electronic manometer connected to the pitot tube, connect the positive side of the manometer to the total pressure connection of the tube (bottom connection), and connect the negative side of the manometer to the static pressure connection of the tube (side connection). This connection will measure velocity pressure (vp), and will be used to determine the actual velocity of the air in FPM (feet per minute).
f. Inserting the pitot tube into the first hole in the duct to the first mark on the tube, hold the tube so the total pressure tip is straight in the direction of airflow. Record the velocity reading at this location. Continue to record each successive velocity reading in the same manner, moving to the next hole in the duct until a complete traverse has been made and each velocity reading recorded.
g. Total all of the velocity readings and divide by the number of readings to obtain the average velocity in FPM.
h. Multiply the average velocity obtained in step g, with the duct net free area in square feet as calculated in step b. FPM x area = CFM of airflow though the duct.

<u>Traverse Example</u>

The number of holes drilled, their distance apart and the number of pitot tube marks are based on a minimum of (16) velocity pressure readings taken at centers of equal areas not more than 6" apart, so that no area exceeds 36 square inches. The first and last hole will be ½ the distance from the edge of the duct (or internal duct liner). Example: Half of 6" = 3"

Example: a duct is 26” x 20”, the holes will be drilled in the 26” side. To determine the holes for the traverse, divide 26” by 5 = 5.2”

The first hole will be ½ the distance from the edge of the duct, so 5.2” x .5 **= 2.6”.**

Second hole will be 2.6” + 5.2” from the edge of the duct = **7.8”**

Third hole is 7.8” + 5.2” from the edge of the duct **= 13.0”**

Fourth hole is 13.0” + 5.2” from the edge of the duct **= 18.2”**

Fifth hole is 18.2” + 5.2” = **23.4”**

Marking the pitot tube is determined in the same manner. The pitot tube will be inserted into the 20” dimension of the duct. We need the number of readings that will be less than 6” between each mark on the pitot tube.

Divide 20”/4 = 5” on center marks of the pitot tube. Again, the first mark will be ½ the distance of the remaining. So the marks on the pitot tube are:

1. 2.5”
2. 7.5”
3. 12.5”
4. 17.5”

<u>Temperature Rise Method of estimating airflow</u>

When either an air handler or package unit has electric heat, then another method is available to estimate airflow through the coil. The only instruments required to use this method are:

1. <u>Electronic thermometer</u>
2. <u>Volt meter</u>
3. <u>Amp meter</u>

For an electric furnace the airflow measurement procedure is to measure the temperature rise across the heater. Allow the unit to operate until the temperature rise stabilizes. Measure the temperature rise again out of the line of sight of the electric heater, along with the incoming volts and current draw in amps to the electric strip heaters. Enter the information into the following formula.

CFM = (Volts x Amps x 3.41) / (1.08 x ΔT)

APPLYING THE FORMULAS

THE PURPOSE OF USING THE FORMULAS IS TO DETERMINE THE PERCENTAGE OF INCREASE IN ENERGY PERFORMANCE THROUGH IMPROVEMENTS IN AIRFLOW AND HEAT TRANSFER RATE.

FORMULA 1: BTUs/hr = *CFM x ΔT x 1.08*

Example 1:

The following measurements are taken.

Before cleaning:

A. Temperature before the coil: 72 degrees
B. Temperature after the coil: 50 degrees
C. ΔT = 22
D. CFM: 200

After cleaning:

A. Temperature before the coil: 72 degrees
B. Temperature after the coil: 45 degrees
C. ΔT = 27
D. CFM = 225

Insert the values into the formula:

Before cleaning:

200 CFM x 22 ΔT x 1.08 = 4752

After cleaning:

225 CFM x 27 ΔT x 1.08 = 6561

Compare by dividing the difference of the “after” and “before” by the “before”:

(6561 - 4752) ÷ 4752 = 0.38

This means energy performance increased by 38%.

NOTE: This does not mean a 38% decrease in the client's electricity bill for HVAC use. That is a more complex calculation with numerous other factors.

This 38% increase in energy performance - and a greater ΔT and CFM - means the coil will cool the air faster, thus having to run less and the airflow will be greater, cooling or heating the space faster, therefore requiring less time for the HVAC system to run to condition the space.

In a spreadsheet format the results would look like this:

	Before Cleaning	After Cleaning
Temp. Before Coil	72	72
Temp. After Coil	50	45
ΔT	22	27
CFM	200	225
FORMULA 1 BEFORE: CFM x ΔT x 1.08	4752	
FORMULA 1 AFTER: CFM x ΔT x 1.08	6561	
Increase in Energy Performance	38%	

FORMULA 2: Total BTUs/hr = CFM x Δh x 4.5

In this instance, we use hypothetical temperature and relative humidity values that could be seen on a typical chilled water evaporator coil. Due to the heat transfer characteristics of how a refrigerant-cooled coil responds versus how a chilled water coil reacts to a reduction in airflow, actual temperature and relative humidity values can vary significantly. In this formula, we include a measurement for relative humidity (or Δh) and temperature.

Before cleaning:

Temperature before the coil = 76°F
Relative humidity before the coil = 65%

Temperature after the coil = 68°F
Relative humidity after the coil 75%

(Again, wet bulb temperature can be used, if desired, as an alternative to the relative humidity reading and plotted, with dry bulb temperature, on the psychrometric chart to determine enthalpy.)

We then find enthalpy value using a psychrometric chart. We enter the readings “before the coil” of 65% relative humidity plus the temperature of 76 degrees.

We find that enthalpy before the coil = 31.94

We now enter the readings for “after the coil,” with a temperature of 68°F and a relative humidity of 75%.

The psychrometric chart shows enthalpy = 28.31

The difference between the enthalpy before the coil and after the coil is Δh.

Δh = 31.94 – 28.31 = 3.63

The measured airflow before cleaning is 1,200 CFM.

After cleaning:

The measured airflow after cleaning is 1,500 CFM

Relative humidity before the coil = 55%
Temperature before the coil = 73°F

Enthalpy = 27.94

Relative humidity after the coil = 99%

Temperature after the coil = 54°F

Enthalpy = 22.50

Δh = 27.94 – 22.50 = 5.44

Applying the formula:

Before cleaning:

BTUs/hr = 1,200 CFM x 3.63 Δh x 4.5 = 19,602

After cleaning:

BTUs/hr = 1,500 CFM x 5.44 Δh x 4.5 = 36,720

Compare by dividing the difference of the "after" and "before" by the "before":

(36,720 – 19,602) ÷ 19,602 = 0.87 or a 87% increase in energy performance.

In a spreadsheet format, it would look like this:

	Before Cleaning	After Cleaning
Temp. Before Coil	76	73
Temp. After Coil	68	54
ΔT	8	19
CFM	1200	1500
Relative Humid. Before Coil	65	55
Relative Humid. After Coil	75	99
Enthalpy Before Coil (Per Psych. Chart)	31.94	27.94
Enthalpy After Coil (Per Psych. Chart)	28.31	22.5
Δh	3.63	5.44
FORMULA 2, BEFORE: CFM x Δh x 4.5	19602	
FORMULA 2, AFTER: CFM x Δh x 4.5	36720	
Increase in Energy Performance	87%	

Identifying Energy Waste During the HVAC Inspection and Cleaning Process

Inspecting and cleaning an HVAC air distribution system is a rare, in-depth look at various components that may not be observed by routine maintenance personnel. The cleaning contractor may encounter a number of issues with the system that are unknown to the system owner and are causing significant energy loss.

Below is a list of common problems found. It is important that the cleaning contractor note and report any such items to the system owner or the owner's representative. These items should only be remedied by those trained and, if necessary, licensed to do so.

Duct and system leakage: Ductwork that is separated at the joints, plenums with broken or rusted-out seams, improperly sealed access openings or doors, and other sources of air leakage can be a significant source of energy waste.

Closed, improperly set, or stuck dampers: Dampers are intended to be set to meet design criteria to provide optimum airflow for a specific system – typically determined by a test and balance (TAB) contractor. These settings can be manual, pneumatic, or automatic through electronic controls. Closed or improperly set dampers result in a system that is not operating at peak efficiency.

Filtration issues: Correct filter choice is best made by those familiar with filtration. Poor filters or dirty filters can restrict airflow unnecessarily or fail to provide adequate particulate removal. Gaps or openings in a filter rack result in unfiltered air going through an HVAC system. This causes a more rapid accumulation of particulate which reduces energy efficiency throughout the system.

Excess flex ductwork: Sometimes flex duct is not cut to meet the needs of the system and, for example, a twenty-foot piece is used where a ten-foot piece would serve. Any added ductwork increases the static pressure of an HVAC system and reduces airflow. Removing excess flex duct will improve system performance.

Damaged ductwork: Ductwork is commonly stepped on in attics or misshapen from a variety of impacts and influences over time. Any significant alteration of shape or volume capacity may restrict airflow.

Failed duct liner: As noted in the first section of this paper, duct liner can fail in a number of ways, impacting airflow and system performance. Typically, the situation needs to be remedied or problems will remain. It is wise to report significant failure of duct liner to the owner of the system.

Clogged or nonfunctioning exhaust systems (bathroom, hallway, operating room, etc.) that fail to remove air per building design: An HVAC system may be in excellent working condition but may fail to perform efficiently because of poor performance or nonperformance from exhaust systems in the building. Bathroom exhausts, hallway exhausts, and similar auxiliary air systems that are dirty, clogged, or nonfunctioning do not provide the airflow for which the building was designed and an inefficient HVAC system will result.

Deteriorating coils: Coils that are corroded, breaking or broken down will not operate as intended, resulting in nonperformance or poor efficiency.

Inefficient energy recovery systems: Some buildings or HVAC systems have energy recovery systems to reduce the need to cool or heat already conditioned air. Any situation that impacts their performance may reduce efficiency.

Missing or broken turning vanes, dampers and other duct components: When parts of an air distribution system are missing or broken, system performance will be negatively impacted.

Poorly functioning or non-functioning HVAC equipment: Poorly or nonfunctioning equipment will not deliver the performance for which the system is designed and energy waste is a common result.

Poor system design: A system that is poorly designed, such as inadequately sized ducts or an HVAC unit that is improperly sized, will significantly impact energy use.

Broken or worn belts and sheaves (pulleys): Broken or worn belts can cause the HVAC system to work harder in order to provide the designed airflow, thus using excessive energy. The same can be true of sheaves that are worn.

Unbalanced Airflow: During the inspection or cleaning process, the cleaning contractor may notice signs of an unbalanced system, such as insufficient or excessive airflow to certain areas that cannot be remedied by the cleaning process. This can be a source of energy waste and is best addressed by a test and balance contractor.

References

National Environmental Balancing Bureau (NEBB) Procedural Standard for Testing Adjusting and Balancing of Environmental Systems 2015 – Eighth Edition

National Environmental Balancing Bureau (NEBB) Testing Adjusting and Balancing Manual for Technicians – 1997 Edition

Duct Traverse Formulas: www.tabcalcs.com . There is also a TABcalcs phone app.

Psychrometric Chart Online: http://www.daytonashrae.org/psychrometrics_imp.html#start

ACR, Assessment, Cleaning, and Restoration, the NADCA Standard