HVAC - How to Size and Design Ducts

An Online Continuing Education Course for Engineers

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HVAC – How to Size and Design Ducts

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Introduction
Airflow problems have plagued the HVAC industry for years. No matter how much money you spend on a high-quality HVAC system, the equipment won't work at its best without properly designed and installed ductwork. Ducts that are not well designed result in discomfort, high energy costs, bad air quality, and increased noise levels.
A well-designed ductwork system should deliver maximum interior comfort at the lowest operating cost while also preserving indoor air quality. The chief requirements of an air conditioning duct system are:

1. It should convey specified rates of air flow to prescribed locations.
2. It should be economical in combined initial cost, fan operating cost and cost of building space.
3. It should not transmit or generate objectionable noise.

A primary issue is the tradeoff between the initial cost of the duct system and the energy cost of the air distribution system. Larger ducts require a larger initial investment, but result in lower fan energy costs over the life of the system. Other issues include space restrictions, noise level, capacity for expansion, appearance etc.
This course will discuss the basic fundamentals and principles of air conditioning duct design and layout.

1.0 Ductwork Design Principles

Starting with the basics, let's start at the most elementary level of airflow fundamentals.

1.1 Basic Definitions

The following basic terminology is extensively used in this course.

- cfm - volume of airflow; cubic feet/minute
- fpm - velocity/speed of airflow; feet/minute
- Area - duct size in square feet

Air volume in cfm can be calculated by multiplying the air velocity by the cross-sectional area of the duct in square feet.

- cfm = fpm x Area

Given any two of these three quantities, the third can readily be determined:

- fpm = cfm/Area
- Area = cfm/fpm

Gauge and Absolute Pressures:
Gauge pressure is indicated on the gauge; absolute pressure is the total of the indicated gauge pressure plus atmospheric pressure. The general equation for absolute pressure is: *Gauge pressure + atmospheric pressure = absolute pressure*

For example, if the gauge reads 10 psig then, using equation, the absolute pressure would be 24. 7 psia: 10 psig + 14.7 psi = 24.7 psia

Ordinary heating, ventilating, and air conditioning duct systems read air pressures at 0.4 psi or less, often much less. 1 psi equals 27.7 inches of water gauge; a common duct pressure of 0.25 inches water column is equal to (0.25 divided by 27.7 in.-wc/psi) = 0.009 psi.

Duct Pressure:
Duct system is pressurized by three pressures

- Static pressure – air pressure in the duct, used for fan selection.
- Velocity pressure – pressure generated by the velocity and weight of the air, used for measuring cfm in a system.
- Total pressure used to find velocity pressure. Static pressure plus velocity pressure equals total pressure

Pressure in the ductwork is measured in inches of water column (in. -wc).

Standard Air Density:
Air has mass - standard air has a density of 0.075 lbs/ ft^3.

System capacity is directly affected by changes in airflow. As air is heated or humidified, its specific volume increases and its density decreases. If the air density is low, more cfm is required to keep the mass flow rate the same. If air density is not considered, many systems will have very low airflow.

Correction for density is however not needed in air conditioning cooling applications, if the temperature is between 40°F to 100°F and up to 1000 ft. elevation.

Fan Capacity:
The volume of air will not be affected in a given system because a fan will move the same amount of air regardless of the air density. In other words, if a fan will move 3,000 cfm at 70°F it will also move 3,000 cfm at 250°F.

Volumetric Airflow Rate:
The volumetric flow rate of air that will be conveyed through the duct in air conditioning system is determined by the cooling/heat load and the desired temperature and the supply air temperature. Since we are not conditioning CFM's of air but rather pounds of it, we need a mass-balance equation.

$$Q\left[\frac{Btu}{h}\right] = \dot{m}\left[\frac{lb}{hr}\right] c_p\left[\frac{Btu}{°F * lb}\right]\Delta T[°F]$$

$$Q\left[\frac{Btu}{h}\right] = CFM * \left(60\,\frac{min}{hr}\right) * \left(\frac{049lbm}{ft^3}\right)0.24\left[\frac{Btu}{°F * lb}\right]\Delta T[°F]$$

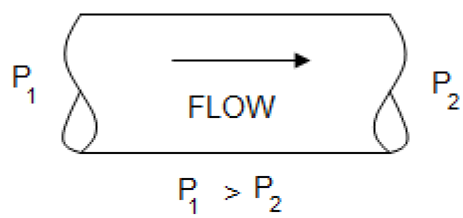
air conditions at 70°F and 1 atm.

$$Q\left[\frac{Btu}{h}\right] = 1.08 * CFM * \Delta T[°F]$$

It is important that the air conditioning ductwork system delivers and return the right amount of air from each room and provide comfort year round. This implies room by room heat loss and heat gain calculations.

1.2 Air Flow Principles

Flow of air is caused as a result of pressure differential between two points. Flow will originate from an area of high energy (or pressure) and proceed to area(s) of lower energy.



Air moves according to three fundamental laws of physics: conservation of mass, conservation of energy, and conservation of momentum.

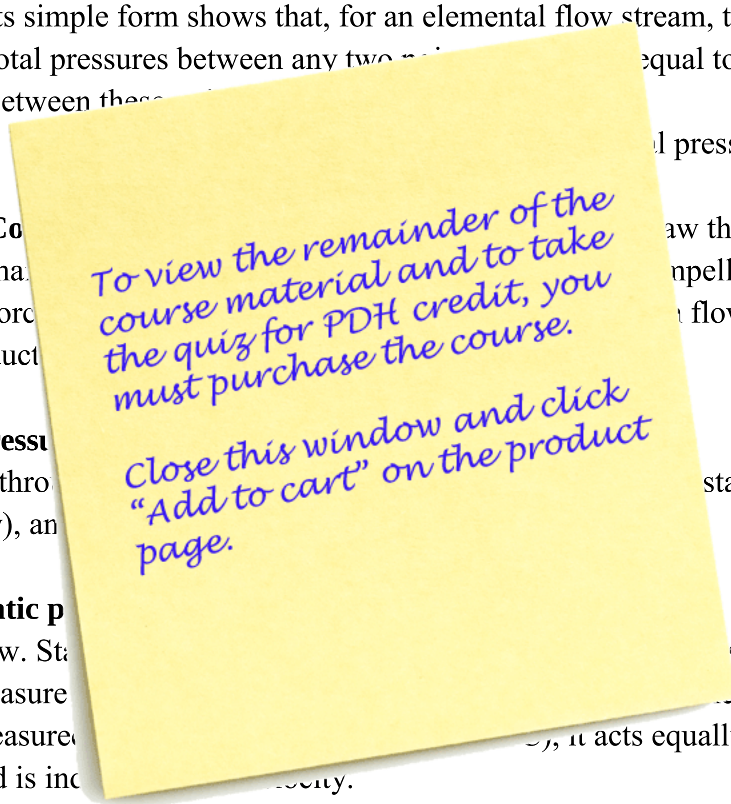
1. **Conservation of mass** simply states that an air mass is neither created nor destroyed. From this principle it follows that the amount of air mass coming into a junction in a ductwork system is equal to the amount of air mass leaving the junction, or the sum of air masses at each junction is equal to zero. In most cases the air in a duct is assumed to be incompressible, an assumption that overlooks the change of air density that occurs as a result of pressure loss and flow in the ductwork. In ductwork, the law of conservation of mass means a duct size can be recalculated for a new air velocity using the simple equation:

$V_2 = (V_1 * A_1)/A_2$
Where V is velocity and A is Area

2. **The law of energy conservation** states that energy cannot disappear; it is only converted from one form to another. This is the basis of one of the main expression of aerodynamics, the Bernoulli equation. Bernoulli's equation in its simple form shows that, for an elemental flow stream, the difference in total pressures between any two p ... equal to the pressure loss between these ...

   ... l pressure) $_2$

3. **Co** ... aw that a body will ma ... npelled by another forc ... flow behaviour in a duct ...



1.3 Total Pressu ...

Airflow thro ... static, dynamic (velocity), an ...

1. **Static p** ... air in the duct to flow. St ... surfaces and is a measure ... duct work. Measure ...), it acts equally in all directions and is inc ... ocity.

2. **Velocity pressure** – Velocity pressure is the pressure caused by air in motion. It is equal to the product of air density and the square of the velocity divided by 2.

   $$VP = 0.5 \times \rho \times v^2$$

   Using standard air, the relationship between V and VP is given by:

   $$VP = \left(\frac{V}{4005}\right)^2$$

   VP will only be exerted in the direction of airflow and is **always positive**.