Air Handling Systems

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Air handling may be defined as the 'science of moving air from one point to another'. The question then, of course is, why would we do this? There are many uses of moving air in both industrial and building scenarios:

- heating and cooling for comfort;
- ventilation of living spaces;
- fume extraction;
- dust extraction; and
- transfer of materials

In its very simplest form, an air handling system could comprise a propeller type fan operating in open space, directing a flow of air at an object or objects. This could be to provide cooling or to dispel fumes or to promote burning. At the other end of the scale an air handling system could comprise many components such as inlet louvres, an air handling unit (AHU), fans, a complex ductwork system, control dampers, various types of terminal unit and outlet louvres etc.

If we need to categorise air handling systems it might be useful to consider them as: those related to heating, ventilation and air conditioning e.g. building related and those related to industrial applications such as fume extraction and materials handling.

The most widely accepted and authoritative source of design criteria in the UK are the Chartered Institute of Building Services (CIBSE) guides. Other sources of useful information include the Building Engineering Services Association (BESA), the UK Building Regulations and, of course the Energy Institute's library.

The starting point in designing an air handling system is almost certainly going to be determining how much air flow is needed to match the task in hand. The task may include many things including: building ventilating; heating and cooling; toilet extract; kitchen extracts; wood chip transportation; exhaust fume removal; and pulverised coal transportation.

A decision then needs to be reached on what classification of pressure system (see later section) should be employed, low, medium or high. This will depend to a large extent on, the type of task and the operating environment. A high-pressure system is not normally suited to a hotel or hospital where noise is a major consideration. A low-pressure system may not be appropriate for say dust extraction from a saw mill where high velocities are required to carry the wood particles and to avoid any settling out that might create a fire or explosion risk.

Once we have determined how much air flow we need and what range of duct velocities we are going to work on we can calculate what size fan we need to deliver the air and overcome the pressure drop of the entire system.

Ductwork systems can be classified as low, medium, and high pressure. The table below, abstracted from the CIBSE Guide B, shows the pressure and velocity ranges which determine these pressure classifications:

High-pressure systems permit smaller ductwork but result in greater friction pressure drop, requiring the fan to generate higher pressures and most likely greater noise generation.

Ductwork construction

In most industrial and building related air handling systems, ducts are used to carry the air being handled. There are many and various approaches to ductwork construction. The type of construction chosen will depend on numerous factors including:

Maximum positive and negative pressures and velocities for low, medium and high-pressure ductwork

System classifications	Design static pressure (Pa)		Maximum air Velocity (m/s)
	Maximum positive	Maximum negative	
Low pressure	500	500	10
Medium pressure	1000	750	20
High pressure	2000	750	40

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- pressure;
- size;
- aesthetics;
- cost; and
- application.

High-pressure systems require stronger ducts to prevent the air from causing the ducting to physically move (vibrate) causing noise and potentially failure of the duct material through fatigue. High-pressure systems are often constructed in round duct work due to its high inherent stiffness.

Very large ducts may be constructed using building materials such as brickwork, concrete and woodwork.

Materials suitable for and commonly used in the construction of ductwork are:

- galvanised steel;
- black steel;
- stainless steel;
- aluminium;
- glass reinforced plastic (GRP);
- polypropylene;
- polyester (textile or fabric ducting); and
- polyvinyl chloride (PVC)

Rectangular ducting is commonly used for low-pressure systems because:

- it can fit well into the available space;
- it can be easily connected to other air handling components such as heating and cooling coils and filters; and
- branch connections can be made more easily than other cross sections.

Rectangular ducting is not generally used for high-pressure systems as it requires strengthening of the flat sides and needs to be sealed to make it suitable for this application.

Circular duct work can be constructed either by 'roll up' or 'spirally wound' in sheet metal. Manufacturers provide standard ranges of pressed and fabricated fittings which makes circular ducting more economical, particularly in low pressure systems. In addition, it is generally relatively easy to install, particularly straight, continuous runs of ductwork.

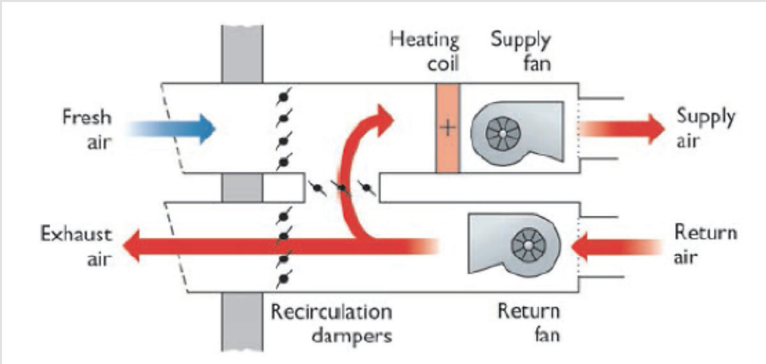
Circular ducting is preferable for high-pressure systems and for systems operating at high negative pressures. Additional stiffening rings may be necessary at high negative pressure.

Flat oval ducting offers the advantages of both circular and rectangular ductwork; e.g. low cost, good use of available space. Flat oval duct is suitable for both positive and negative pressure applications.

The definitive source of information on the construction of HVAC type duct work is DW144 produced by BESA.

Virtually every commonly found air handling system has at its core one or more fans. Fans are used to drive air around a system and to move air from one place to another.

Schematic of a typical air handling unit



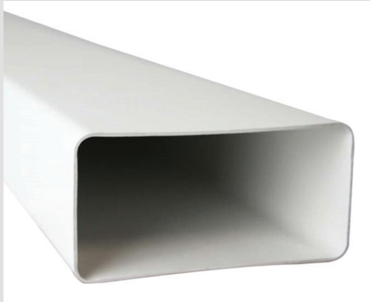
There are several different types of fan and numerous sub types. Again, it is beyond the scope of this article to enter into too much detail on this subject. Fans probably justify their own CPD module. However, they generally share the following common components:

- **casing -** stationary parts of the fan which guide air to and from the impeller;
- **guide vanes -** a set of stationary vanes; and
- **impeller:** the part of a fan which rotates and imparts movement to the air.

Basic types of fan

This article considers the basic types of fan:

Axial-flow fans comprise an impeller in a cylindrical casing. Refinements may include guide vanes, fairings and expanders to improve their performance. These fans are of high efficiency, they may be staged or placed in series and when fitted with guide vanes the aggregate pressure developed is proportional to the number of stages for a given volume. A two-stage fan may have contra rotating impellers.



Plastic rectangular ductwork is often used for low-pressure systems

Axial-flow fans tend to be noisy and are more generally to be found in industrial rather than building applications.

Bifurcated fans can handle atmospheres which may damage the fan motor, for instance: saturated and dust laden atmospheres, hot and/or corrosive gases. They are normally direct drive with the motor isolated from the system air stream.

In a centrifugal fan air flows into the impeller axially, turns through a right angle within it and is discharged radially by centrifugal force. There are two main types:

- **forward-curved:** the impeller has a relatively large number of short forward-curved blades. The air is impelled forward in the direction of rotation at a speed greater than the impeller tip speed.
- **backward curved:** the air leaves the impeller at a speed less than the impeller tip speed and the rotational speed for a given duty is relatively high. The impeller has blades of curved or straight form, inclined away from the direction of rotation.

Backward-curved fans are noted for their high efficiency and low noise. They are typically used for general ventilation, dust collection where the fan is on the clean side of the dust collector, combustion air and drying.

Forward-curve fans are generally used where large volumes of air at relatively low pressures are required. Typically used in HVAC applications.

Propeller fans comprise an impeller of two or more blades of constant thickness, usually of sheet steel, fixed to a centre boss and are designed for orifice or diaphragm mounting. They have high volumetric capacity, very low pressure development. The efficiency of propeller fans is low.

Cross-flow or tangential comprise a forward-curved centrifugal type impeller but with greatly increased blade length and the conventional inlets blocked off. The impeller runs in a half casing with conventional discharge but no inlet. Air is scooped inwards through the blade passages on the free side, but at the opposite side of the impeller, due to the influence of the casing, the air obeys the normal centrifugal force and flows out of the impeller and through the fan discharge. The discharge opening is generally narrow so the fan is not easily applicable to ducting but is well suited to fan coil units and electric space heaters.

In mixed-flow fans the passage of air through the impeller has both axial and radial components, hence the term mixed-flow. Mixed-flow fans are of high efficiency and can be designed for higher-pressure duties than axial flow fans.

Understanding the fan laws

In order to acquire a good knowledge of how fan design and application can influence energy efficiency it is essential to have some understanding of the fan laws:

- the inlet volume varies directly as the fan speed;
- the fan total pressure and the fan static pressure vary as the square of the fan speed;
- the power required to drive the fan impeller varies as the cube of the fan speed.
- the fan total pressure, the fan static pressure and the fan power all vary directly as the mass per unit volume of the air which in turn varies directly as the barometric pressure and inversely as the absolute temperature;
- the inlet flow rate varies as the cube of the fan size;
- the fan total pressure and the fan static pressure vary as the square of the fan size; and
- the air power (total or static) and impeller power vary as the fifth power of the fan size.

Cube of the fan speed

The most important of these laws or rules from an energy efficiency perspective is the fact that the power required to drive the fan varies as the cube of the fan speed.

Therefore, for example, if the motor shaft speed is 100 rpm and its power is 10 kW, then:

- increasing the shaft speed to 110rpm will increase the power to 10 x (110 / 100)3 = 13.3 kW;
- decreasing the shaft speed to 90 rpm will reduce the power to 10 x (90 / 100) = 7.3 kW

As a result, optimising the systems to achieve small reductions in the motor shaft speed can have a substantial impact on the motor's power requirements and energy consumption.

In general, energy is imparted to the air in an air handling system by a fan. As the air travels through the system it loses energy due to the frictional losses exerted on it by the ductwork.

A very necessary component of designing an effective air handling system is being able to determine the pressure drops through the system. This will enable the selection of the type and power of the fan/s.

As mentioned elsewhere the design of the ductwork system and other components such as grilles, dampers and heat exchangers will depend on factors including space, noise, and economics.

Generally, the larger the ductwork etc. that is used the lower the pressure drop will be but the higher the capital cost of the system will be. Likewise, the smaller the system the higher the fan power and thus the running costs.

The UK Building Regulations set limits on the fan power that systems require. This is another important consideration in system design.

There are numerous possible approaches to pressure drop calculation. These range from a 'first principles' approach to using established empirical data and of course commercially available computer-based applications.

In addition to calculating the pressure losses in straight sections of ductwork account must also be made for grilles, dampers, bends, tees, heat exchangers, changes of section etc.

There are two main types of centrifugal fan: forward curved and backward curved

The CIBSE publication 'Improve life cycle performance of mechanical ventilation systems' – CIBSE TM30: 2003[viii] covers this area in much detail.

In many building-related air handling systems, air handling units (AHU) will be found. These are 'boxes' containing various components that are required in HVAC applications.

An AHU may contain various components including: inlet grilles, fans, volume control and recirculation dampers, various heat exchangers and filters.

Control of air volume

The control of the volume of air flowing in all or parts of an air handling system may be achieved in a number of ways:

Dampers may be of either the butterfly or multi-leaf type. They may be adjusted manually in either fixed or variable mode. They may also be adjusted by a control motor actuator.

Butterfly (or single vane) dampers are usually best suited for open/closed or isolation duties as the sealing periphery of a single vane is minimal relative to the duct area.

Multi-vane (or louvre) dampers, offer very good flow control characteristics but are more expensive than butterfly dampers.

Controlling fan speed as a means of varying volume, where possible and practicable offers significant advantages over damper control in terms of energy use and noise.

The most popular type of electric motor is the squirrel cage induction motor. For many decades it has been easily possible to produce two or three speed motors by including extra windings.

To produce infinitely variable speed motor control inverters can be used with conventional induction motors.

Electronically commutated motors also allow energy-efficient, infinitely variable fan speed and are becoming popular in air handling units.

In buildings and industry air handling systems are very common. Among the many factors to consider are: -

- **safety** – e.g., will dust collect in the ductwork creating a fire or explosion risk;
- **effectiveness** – will the system deliver air at the correct volume?;
- **noise** – will the system make an unacceptable amount of noise?;
- **energy efficiency** – has the duct design, fan selection and control strategy optimised energy use?;
- **aesthetics** – does the system look good in its surroundings? e.g., underground duct, factory, pizzeria.

Careful design should be able to accommodate all these considerations. ■

ENTRY FORM

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Questions

1. What is the air velocity range for a low velocity ductwork system?

☐ 5-15 m/s
☐ 3-5 m/s
☐ 30-50 m/s
☐ Above 50m/s

2. How can variable volume control be achieved most energy efficiently?

☐ Butterfly damper
☐ Variable fan speed drive
☐ Multi vane damper
☐ Two speed fan

3. What type of ductwork construction might one typically find for exhaust fume extraction in a vehicle workshop?

☐ Rectangular sheet metal
☐ Spiral round
☐ Brick work
☐ UPVC Plastic

4. What type of fan would you most commonly find inside an air handling unit?

☐ Centrifugal
☐ Axial
☐ Bifurcated
☐ Propeller

5. Which of these duct construction methods is best suited to a high-pressure air handling system?

☐ Round
☐ Rectangular
☐ Flat oval
☐ Flexible

6. What might be the first decision to be made when designing an air handling system?

☐ The ductwork construction method
☐ The required volume of air
☐ The power of the fan
☐ The type of system e.g. low, medium, high pressure

7. Which of these factors is likely to be most important when designing an air handling system to be installed in a hospital?

☐ Capital cost
☐ Aesthetics
☐ Noise
☐ Ductwork size

8. What information do you need to calculate the pressure drop in an air handling system?

☐ The volume of air flow
☐ The type of ductwork construction
☐ The type fans used
☐ The desired noise level

9. What is a potential risk in a saw dust extract system?

☐ High running cost
☐ High capital cost
☐ Noise
☐ Fire or explosion

10. What is one of the advantages of a backward curved centrifugal fan impeller?

☐ High efficiency
☐ Low cost
☐ Very low noise
☐ Can withstand dusty environment

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