Fan and air movement essentials

1 Properties of air

For the purposes of this section we will assume that it is air that will be moved by the various types of fans.

The air we breathe is made up of a mixture of gasses - nitrogen 78%, oxygen 21% and 1% trace gasses including carbon dioxide. All of these gasses have mass In the atmosphere, the weight of these gasses produce a pressure (approx, 101,325 Pa at sea level depending on the weather).

The mass and pressure result in air having a density 1.2kg m3 which is considered the standard density of air. Air Density changes with conditions and can be affected by temperature as well as atmospheric variations due to high and low pressure systems. Higher or lower altitude also corresponds with higher or lower density and pressure.

2 Air flow and air pressure

As fans provide the means to move air, the relevant variables are the volume flow rate required and the pressure that must be overcome in order to deliver the volume. The graphical intersection of volume air flow and pressure required (in an X Y scatter chart) describes the fan performance duty needed for a particular application.

2.1 Measurement of air flow

Air flow is the measurement of the quantity of air that is conveyed in a given time period;

L/s (litres per second)

$m^3\ s^{-1}$ (cubic metres per second)

$m^3\ hr^{-1}$ (cubic metres per hour)

CFM (cubic feet per minute)

2.2 Measurement of air pressure

Air pressure is the force per unit area exerted by air;

Pa (Pascals)

KPa (Kilopascals)

In.WG (Inches Water Gauge)

Mm.H_2O (mm water gauge)

PSI (Pounds per square inch)

In relation to fans and air movement there are five pressure variables to be considered.

Static pressure

The difference between the absolute pressure at a point in an airstream, usually inside a duct and the pressure of the outside atmosphere. Static pressure acts equally in all directions, is independent of velocity and is a measure of the potential energy available in an air stream.

Velocity pressure

Is the measure of energy available in an airstream and is always positive.

Total Pressure

The sum of static and velocity pressure. It is a measure of the total energy available in an air stream.

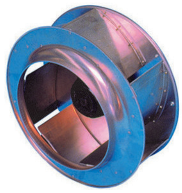
Fan total pressure

The difference between the mean total pressure at the fan outlet and the total pressure at the fan inlet.

Fan static pressure

The fan static pressure is a defined quantity used in rating fans and cannot be measured directly. It is the fan total pressure minus the velocity pressure corresponding to the mean air velocity at the fan outlet. Note that it is not the difference between the fan static pressure at the outlet and the static pressure at the inlet; that is, it is not the external system static pressure.

Fan impeller types



Centrifugal

Axial
sickle blade type)

Mixed Flow

3 How fans work

A fan is a rotating bladed device which continuously applies energy to air or gas passing through it. There are three main components to a fan; the impeller, a means to drive the impeller, and the casing.

Energy is transferred to the air by rotation of the impeller being one of the three main types commonly used; centrifugal, axial or mixed flow.

In the centrifugal type, it is the centrifugal force generated by the mass of air contained within the impeller at any given instance, as well as the force exerted by the angle of the blades to the entering air which gives it both static and velocity pressure and therefore moves air through the system.

In the axial type there is little or no centrifugal action; the blades being set at an angle relative to the direction of air entry generate a lift or pressure difference.

In the mixed flow type, energy is imparted to the air by a combination of centrifugal force and lift. As the name suggests, this type of fan displays a mix of characteristics seen in both axial and centrifugal fans.

The casing is not simply an enclosure for the impeller to channel air in a certain direction. It plays an important part in the aerodynamic performance particularly in the case of centrifugal and mixed flow fans when it is often the major element which converts velocity energy to useful potential energy (static pressure) and in axial fans where impeller tip clearance is important.

4 Fan type characteristics

4.1 Centrifugal

Air enters the impeller axially and is discharged radially into a volute or scroll shaped casing. These fans offer medium to low volume flow rates at moderate to high pressures. The main varieties are characterised by the type and angle of the impeller blades.

A) Backward types may consist of aerofoil sections or single thickness blades, the latter being either curved or straight. These impellers typically have few blades. The pressure curve generated by this impeller type is relatively steep over the working range and the power curve has a non-overload characteristic. Very good efficiencies are possible with this type of impeller.

B) Forward curve types are characterised by a larger number of shallow blades sloping forward in the direction of rotation. The power curve for this type of fan rises steeply from zero to maximum flow making this type prone to overloading its driving motor if operated beyond the rated duty point. It will handle relatively large volumes of air at lower operating speeds however, overall efficiency is less than backward inclined blading.

C) Radial blades produce a near straight power curve from a minimum at zero flow to a maximum at maximum air flow although the curve is not as steep as for a forward curve impeller. The blades tend to be self cleaning and can handle moderately dirty conditions.

4.2 Axial

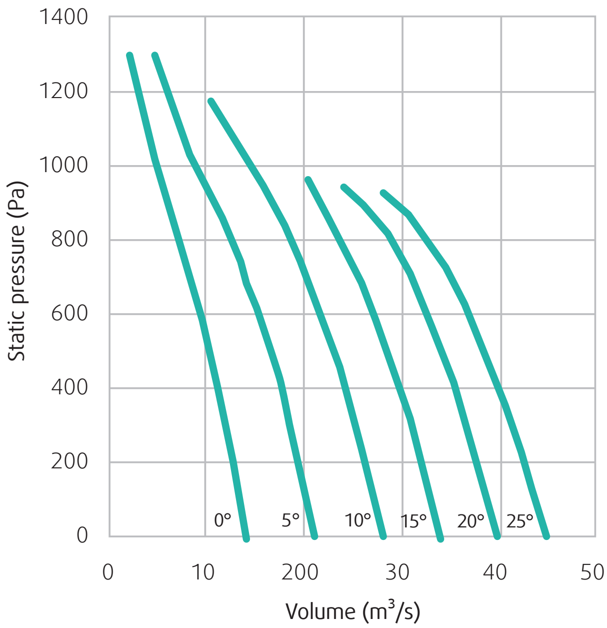
In this type, air enters and leaves the fan axially in a straight through configuration. Duties are usually medium to high volume flow at medium to low pressures. In its simplest form a single impeller is direct driven by a motor in a cylindrical casing. The discharge flow embodies a pronounced swirl or twist to the airstream which may, if not corrected, materially increase the resistance of the downstream portion of the system. This swirl can be removed by fitting guide vanes either upstream or downstream of the fan. The removal of swirl increases the efficiency of the fan. A further variation to remove swirl is the use of two independently driven contra-rotating impellers within a single casing. Axial types have non overloading power characteristics and can display very good efficiencies.

4.3 Mixed Flow

This type of fan has an air path through the impeller which has characteristics of both axial and centrifugal types. Mixed flow impellers are designed to provide both axial and radial discharge. Higher fan static pressures are achievable with this type of impeller compared to axial fans.

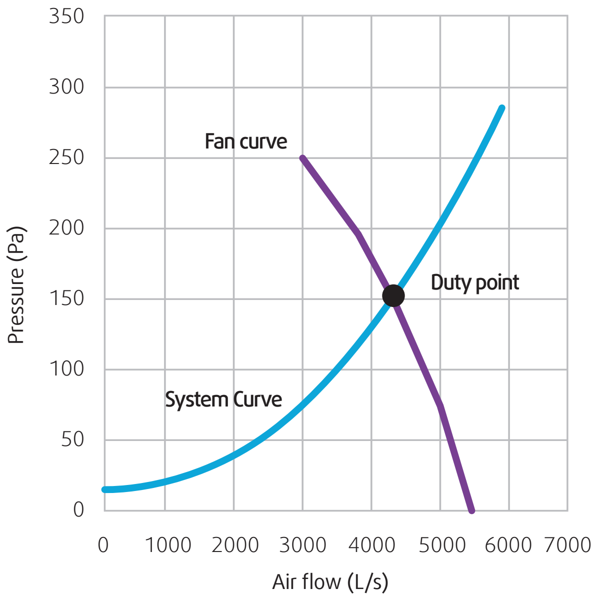
5 Presenting Fan Performance

Fan performance is typically represented graphically using x-y scatter charts with points plotted at intersections of static pressure and air flow. Data series presenting the working range of the fans are plotted to graphically illustrate performance as a line or curve. Multiple fans of similar type, for example axial flow fans with adjustable pitch blades, are presented as groupings of curves within the one graph.



5 Fan Duty

The points along the fan curve represent the outflow of air at varying levels of system resistance (static pressure). The required fan performance for flow rate at the designed pressure level is the duty point that the fan is required to meet. Represented graphically, the duty that is required is a point along a calculated curve known as the system curve.



It should be remembered that the fan performance presented in this catalogue has been derived through testing to recognised standards. In arriving at duty requirements for fans, designers are advised to pay close attention when determining overall system resistance to ensure that fans perform to published levels.

6 Fan Applications

Although typically thought of as a means to provide airflow in air-conditioning systems, fans are applied to a diverse range of air movement tasks in a wide range of environments. The following sections provide an overview of more specialised fan applications.

6.1 Smoke Spill

Such systems are intended to limit and control the movement of smoke during a fire.

The most common technique involves pressurizing the areas on either side of the compartment where the fire is located and exhausting from the fire area.

This method creates a 'pressure sandwich' which tends to move air (and thus smoke) from the protected areas towards the fire whilst moving smoke out of the fire area. Although this does introduce fresh oxygen to the fire area, most systems are aimed at protecting the occupants and equipment in the compartments adjacent to allow evacuation and to allow fire personnel clear access to the fire to extinguish it.

Generally in Australia, smoke spill fans fall into two categories.

Tested to withstand 200°C for two hours.

Tested to withstand 300°C for one half of one hour.

If an area that requires smoke spill fans has fire sprinklers serving it, then fans tested for 200°C or two hour are acceptable.

Smoke-spill fans have to be tested to Standard AS4429 and conform with the requirements of AS/NZS1668.1.

6.1 Smoke Spill Fans (continued)

Smoke spill fans can be roof mounted, plate mounted, in line axial, in line centrifugal.

For 300°C 30min smoke spill Fans in buildings without sprinkler systems, dampers shall remain open in the event of fire.

6.2 Hazardous Location Fans

The selection of fans in hazardous locations has to take into account four sets of information.

The area classification.

The gas group.

The "T" rating or ignition temperature of the hazard.

The required "IP" rating of the apparatus.

6.2.1 Area Classification

The areas are classified into ZONES, and these zones are based on the frequency of the appearance of an explosive atmosphere and the duration for which it can last.

Summarised as follows:

Gases and Vapours

Zone 0

Area in which an explosive gas-air mixture is continuously present or present for long periods.

Zone 1

Combustible or conductive dusts are present. Area in which an explosive gas-air mixture is likely to occur for short periods in normal operation.

Zone 2

Area in which an explosive gas-air mixture is not likely to occur, and if it occurs it will only exist for a very short time due to an abnormal condition.

Dust

Zone 20

Area in which an explosive dust-air mixture is continuously present or present for long periods.

Zone 21

Combustible or conductive dusts are present and is likely to occur for short periods in normal operation.

Zone 22

Area in which an explosive dust mixture is not likely to occur, and if it occurs it will only exist for a very short time due to an abnormal condition.

6.2.2 Gas Groups

Gas Groups are divided into two categories.

Group 1.

Coal Mining Industry. (Methane)

Group II

Other Industries.

Group II is further subdivided as follows and the representative gases for each group are shown as well:

Group I – Methane

Group IIA – Propane

Group II – Ethylene

Group IIC – Hydrogen

6.2.3 Temperature or "T" rating

The source of ignition in a hazardous area can be an arc or a spark or even a hot surface.

Since electrical equipment generates heat in normal operation we need to ensure that a hot surface on electrical apparatus cannot ignite a surrounding explosive gas atmosphere or a dust cloud or layer.

All hazardous materials have what is known as an "Ignition Temperature". This is the minimum temperature at which the hazardous material when mixed with air will ignite and sustain combustion, without an ignition source (auto-ignition or spontaneous ignition).

The temperature of a layer on the surface of the equipment.

Eg. if the ignition temperature of the dust layer is 275° C then the equipment T rating must not exceed 200°C or T3.

6.2.4 Ingress Protection (IP) Ratings

<table>
<tr><th>Designation</th><th>First digit protection against contact and ingress of foreign bodies.</th><th>Second digit protection against water.</th></tr>
<tr><td>IP44</td><td>Protection against contact with parts inside the enclosure by foreign objects including wires with a diameter greater than 1mm.</td><td>Protection against water sprayed from any direction.</td></tr>
<tr><td>IP54</td><td rowspan="3">Protection against contact with parts inside the enclosure by foreign objects including dust. Protection against dust ingress is not total but not in amounts that will interfere with the operation of the equipment.</td><td>Protection against water sprayed from any direction.</td></tr>
<tr><td>IP55</td><td>Protection against beamed water directed by a nozzle.</td></tr>
<tr><td>IP56</td><td>Protection against strongly beamed water jets or heavy seas.</td></tr>
<tr><td>IP65</td><td rowspan="2">Complete protection against contact with parts inside the enclosure by foreign objects including dust.</td><td>Protection against beamed water directed by a nozzle.</td></tr>
<tr><td>IP66</td><td>Protection against strongly beamed water jets or heavy seas.</td></tr>
</table>

6.2.5 Types of motors used in Hazardous locations

Temperature Classification

To prevent ignition of gases, dust or vapours in hazardous areas it is essential that external motor components do not exceed the flash point of ignitable materials.

Group I Gases – Max. surface temp. 150°C

Group II Gases and Dusts are assigned a Temp. Class (T) in relation to the maximum equipment surface* temperature allowable

T1 – 450°C	T4 – 135°C
T2 – 300°C	T5 – 100°C
T3 – 200°C	T6 – 85°C

* For EXD motors, the temperature relates to the external surface of the motor.
  For protection levels above EXD, the internal temperature is also taken into account.

Levels of Protection - Motors

EXN

Is a level of protection that states the motor will in normal operation not ignite a surrounding area, and that any ignition is unlikely to happen.

DIP

These motors use suitable enclosures to prevent arcs and sparks or heat to be liberated inside the enclosure to ignite any exterior dust on or near the motor. Used in heavily dust laden environments.

EXD

These are motors that are built to withstand an internal explosion within the motor casing and will not transmit any flame or spark that could ignite surrounding gas or vapours. They also operate at external surface temperatures that do not allow ignition of surrounding gas or vapours.

Three Phase Motors

EXD motors are certified to Class I, Zone 1 protection (including Gas groups IIA and IIB).

EXE

Exe protection is also known as increased safety, this level of protection is such that the motor does not produce arcs or sparks under normal use. Generally used in spray booth applications. Motors hold certification to EXE Class I, Zone I protection (including Gas groups IIA, IIB, IIC.

Temperature classification T3 and ingress protection IP66

Specification Range EXD, EXE Three Phase Motors

Insulation: Class F

Type: TEFC

Ingress Protection: Up to IP66

Voltage: Up to 500 Volts

Frequency: 50Hz - 60Hz

Standards Met

Motors certified are compliant with AS/NZS60079.0:2005, AS/NZS60079.7:2006 which also covers classifications EXN and DIP.

6.3 Fresh Air Supply Fans

Fresh air is introduced to air conditioned spaces to maintain adequate ventilation rates and to flush out contaminants. The level of fresh air introduced depends mainly on the type and function of the space and the number of occupants utilising the area at any given time.

These fans should deliver fresh air ventilation rates in accordance with Australian Standard (AS) 1668.2-2012.

These fans are also known as supply air fans and can be roof units, in line axial, centrifugal or any type of fan depending on the design.

6.4 Car Park Exhaust and Supply Fans

Compliance with AS1668.2 requires that the internal environment of a car park is safe for occupants and that if the internal air quality is acceptable to health, it is concluded that the air quality of any discharges either through mechanical or natural ventilation are equal to or better than that in the car park.

Car park exhaust fans should always have aluminium impellers, F class motors are acceptable.

Car park supply fans can have plastic, glass reinforced nylon or fibre reinforced plastic impellers, again class F motors are acceptable.

6.5 Stairwell Pressurisation

Stairwells are frequently the primary escape routes for the occupants of a building in a fire emergency.

In addition, the stairwells may be the primary access routes for the fire fighting teams responding to the emergency. Thus, it is critical that they remain clear of smoke for as long as is necessary to safely evacuate the building and bring the fire under control.

Most high rise buildings employ a stairwell pressurization system to keep the stairs clear of smoke while operating at a low enough pressure that an average person can open the doors to enter or exit the stairwell on their way to safety.

Stairwell pressurization fans are fairly standard in construction and are usually in line axial type, but not limited to this type of fan. Standard motors meet the code requirements.

7 Fan Laws

7.1 About Fan Laws

It is not practical to test fans of every size with differing variables such as gas density or rotational speed. Fortunately, by the use of fan laws, the performance of geometrically similar fans of different sizes or speeds can be predicted with sufficient accuracy for practical purposes. These laws are most often used to calculate changes in flow rate, pressure, sound and power of a fan when size, rotational speed or gas density is changed. In the following laws, the suffix '1' has been used for the initial known values and the suffix '2' for the changed values and the resulting calculated value.

7.1.1 Fan Law for Volume

Volume $\propto$ Speed. Volume flow changes in direct proportion to fan speed.

$$Q_2 = Q_1 \left(\frac{N_2}{N_1}\right)\left(\frac{D_2}{D_1}\right)^3$$

Where: Q = flow rate, N = fan rotational speed, D = impeller diameter

7.1.2 Fan Law for Pressure

Pressure $\propto$ Speed^2. Pressure changes in direct proportion to the square of the fan speed ratio.

$$P_2 = P_1 \left(\frac{N_2}{N_1}\right)^3\left(\frac{D_2}{D_1}\right)^3\left(\frac{p_2}{p_1}\right)$$

Where: P = pressure N = fan rotational speed,
D = impeller diameter, p = density of air.

7.1.3 Fan Law for Power

Power ∝ Speed³. Power required changes in direct proportion to the cubed power of fan speed.

$$W_2 = W_1 \left(\frac{N_2}{N_1}\right)^3 \left(\frac{D_2}{D_1}\right)^5 \left(\frac{p_2}{p_1}\right)$$

Where: *W* = power *N* = fan rotational speed, *D* = impeller diameter, *p* = density of air

7.1.4 Fan Law for Sound

Power ∝ Log (speed).

$$Lw_2 = Lw_1 + 50\,Log_{10}\left(\frac{N_2}{N_1}\right) + 70\,Log_{10}\left(\frac{D_2}{D_1}\right) + 20\,Log_{10}\left(\frac{p_2}{p_1}\right)$$

Where: *Lw* = sound power level, *N* = fan rotational speed,
D = impeller diameter, p = density of air

We are the safe choice.

ISO 9001 Quality Management Systems CERTIFIED

Pacific Ventilation Pty Ltd

AU 1300 733 833
NZ 0800 100 326

Pacific Ventilation

www.pacificventilation.com

PV00101_SEPT_2020_Version 1.0.0