FAN ENGINEERING

SECTION INDEX

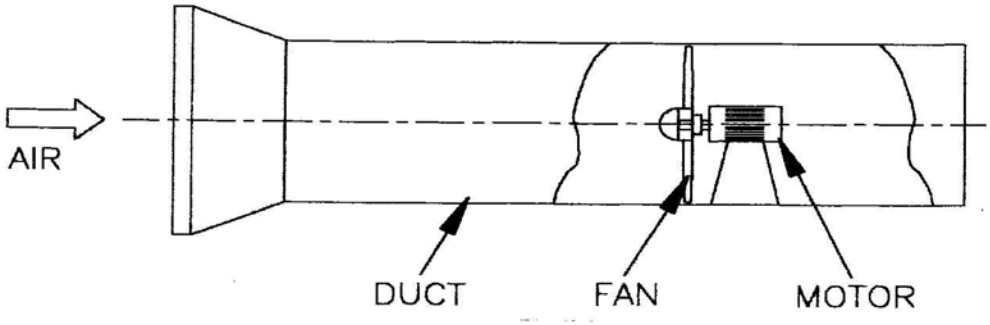
01. FAN BASICS

Axial Flow Fans : A Fan is a device that is designed to move a specified volume of air (flow) against moderate pressure (resistance). A fan induces an airflow by virtue of its blades; a blade moves air by generating a lift force when in motion through the air. An axial flow fan is a fan in which the flow of air is substantially parallel to the axis of rotation.

Static Pressure : A Fan moving air must work to overcome resistance to the flow that arises due to various obstructions in the flow path. This works is termed as velocity pressure and is expressed as mm of wg.

Velocity Pressure : In addition to the above, a fan must also work to accumulate air to its suction side and move it to the discharge side. This work is termed as velocity pressure and is expressed as mm wg.

Total Pressure : The total work a fan must do to move a specified volume of air against the static pressure plus the velocity pressure is defined as total pressure of the system and is expressed in millimeters or mm wg.



Efficiency : The measure of how well a fan does work against the total pressure to move a given volume of air is termed as Fan Total Efficiency. In general, a non – uniform air stream(flow) results in a less efficient fan. A fan equipped with a duct having proper inlet and outlet shapes, allows for a more uniform air stream (flow) and thus dramatically improves the efficiency of the fan; in fact, if properly designed, a ducted fan can achieve efficiencies up to 85%.

02. ABBREVIATIONS

ABBREVIATION	TERMS
bhp	BRAKE HORSE POWER
bkW	BREAK KILOWATTS
^{0}C	CELCIUS
CFM	CUBIC FEET PER MINUTE
cm	CENTIMETER
^{o}F	FAHRENHEIT
FPM	FEET PER MINUTE
ft	FEET
Hg	MERCURY COLUMN
hp	HORSE POWER
in	INCH
kg	KILOGRAM
kW	KILOWATT
lb (lbs)	POUND (POUNDS)
m	METER
min	MINUTES
mm	MILIMETER
Pa	PASCAL
rpm	REVOLUTIONS PER MINUTE
rps	REVOLUTIONS PER SECOND
s	SECOND
W	WATT
wg	WATER GAUGE / WATER COLUMN

03. SYMOBLS / NOTATIONS / UNITS

SYMBOLS	DESCRIPTION	UNITS	
		METRIC	FPS
A	NET FREE FAN AREA	m^2	ft^2
D	FAN DIAMETERER	m	ft
d	SEAL DISC DIAMETER	mm	in
H_i	FAN INPUT POWER	kW	hp
H_1	FAN INPUT POWER AT DUTY POINT 1	kW	hp
H_2	FAN INPUT POWER AT DUTY POINT 2	kW	hp
H_O	FAN OUTPUT POWER	kW	hp
Ho_S	FAN OUTPUT POWER (STATIC)	kW	hp
HP	HORSE POWER	hp	hp
N	FAN SPEED	rpm	rpm
N_1	FAN SPEED AT DUTY POINT 1	rpm	rpm
N_2	FAN SPEED AT DUTY POINT 2	rpm	rpm
η_t	FAN TOTAL EFFICIENCY	%	%
η_s	FAN STATIC EFFICIENCY	%	%
P_t	TOTAL PRESSURE	mm wg	in. wg
P_s	STATIC PRESSURE	mm wg	in. wg
P_v	VELOCITY PRESSURE	mm wg	in. wg
P_1	PRESSURE AT DUTY POINT1	mm wg	in. wg
P_2	PRESSURE AT DUTY POINT 2	mm wg	in. wg
ρ	AIR DENSITY	mm / m^3	lbs /ft^3
ρ_1	AIR DENSITY DUTY POINT 1	kg / m^3	lbs /ft^3
ρ_2	AIR DENSITY DUTY POINT 2	kg / m^3	lbs /ft^3
Q	AIR FLOW RATE	m^3 / s	CFM
Q_1	AIR FLOW RATE AT DUTY POINT 1	m^3 / s	CFM
Q_2	AIR FLOW RATE AT DUTY POINT 2	m^3 / s	CFM
T_S	FAN TIP SPEED	m/s	FPM
V	AIR VELOCITY	m/s	FPM
V_1	AIR VELOCITY AT PLANE 1	m/s	FPM
V_2	AIR VELOCITY AT PLANE 2	m/s	FPM

04. DEFINITIONS & TERMINOLOGY

Air Density (ρ) : The mass per unit volume of the air, expressed in kg/m^3 or lb / ft^3

Air Flow Rate (Q) : The volume of air moved by the fan per unit of time, expressed in CFM (cubic feet per minute) or m^3/s.

Air Power (Static) : That part of the energy, per unit time, imparted by the fan to the air in overcoming static pressure (Ps) from that at the inlet to that at the outlet.

Air Power (Total) : That part of the energy, per unit time, imparted by the fan to the air by increasing its total pressure (P_t) from that at the inlet to that at the outlet.

Fan: A device for moving air, which utilizes a power driven rotating impeller. A fan shall have at least one inlet and one outlet.

Axial Flow Fan : A fan in which the flow of air is substantially parallel to the axis the impeller rotation.

Fan Characteristics: The curves depicting the relationship between air flow rate, total pressure, fan power input and fan total efficiency at a specified angle and RPM

Fan Duty (Static) : The volume of air to be moved, by the fan at a specified static pressure (P_s).

Fan Duty (Total) : The volume of air to be moved, by fan at a specified total pressure (P_t)

Fan Power Input(H_1) : The energy input, per unit time, required to drive a fan, expressed in Break Horse Power (bhp) or Break Kilowatt (bkW).

Fan Speed (N) : The number of revolutions of the fan about its axis per unit time, expressed in revolutions per minute (RPM)

Fan Total Efficiency (η_t): The ratio of air power (total) to the fan power input

…… 04 DEFINITIONS & TERMINOLOGY

Fan Static Efficiency (η_s) : The ratio of the air power (static) to the fan power .

Stall : The region of instability in fan performance caused by the separation of the air flow from the surface of the fan blade. The stall condition is depicted by a dip in the performance curve.

Standard Air : Atmospheric air having a specific weight of 1.2 kg / m^3 which is dry air at 20^o C and 50% relative humidity with a barometric pressure of 760 mm Hg.

Static Pressure Margin : The pitch angle margin available between the selected operating point and stall point on the performance curve.

Static Pressure (Ps) : The sum of all resistance to the path of air flow in a given system which a fan must overcome to move a specific volume of air, expressed in mm wg or in wg or Pascal (Pa).

Tip Clearance : The clearance between the fan blade tip and the fan casing wall.

Total Speed (Ts) : The linear speed at the fan blade tip at a given fan rpm, expressed in ft./min. or m/s.

Total Pressure (P_t) : The air pressure, which exists by virtue of the degree of compression and the rate of motion. It is the sum of the static pressure and velocity pressure at any given point in a system.

Velocity (V) : The rate of air flow divided by the net area of the air flow, and is expressed in m/s or ft /min.

Velocity Pressure (Pv) : The portion of air pressure which exists by virtue of the rate of motion only, expressed in mm or in wg or Pascal (Pa).

05. METRIC / FPS CONVERSIONS

PARAMETER	METRIC UNIT	METRIC TO FPS CONVERSION FORMULA	EQUIVALENT FPS UNITS
LENGTH	1 m	x 3.2802	3.2802 ft
MASS	1 kg	x 2.2046	2.2046 lbs
TEMPERATURE	0^{o} C	1.8 x ^{o}C +32	32^{o} F
FORCE	1 N	x 0.22481	0.22481 lbs.
FLOW RATE	1 m^3/s	x 2118.9	2118.9 CFM
	1 m^3/hr	x 0.58858	0.5884 CFM
VELOCITY	1 m/s	x 32.8083 x 196.85	32.8083 ft / s 196.85 FPM
PRESSURE	1 N/m^2	x 0.00402264 x 0.00029530	0.00402264 in. wg 0.00029530 in. Hg
	1 Pa	x 0.0040264	0.0040264 in. wg
POWER	1 W	x 0.0013410	0.0013410 hp
TORQUE	1 N-m	x 8.8507	8.8507 lb - in
SPEED	1 rps	x 60	60 rpm
DENSITY	1 kg/m^3	x 0.062428	0.062428 lbs / ft^3

06. USEFUL FORMULAS & FAN LAWS

A. USEFUL FORMULAS

- AIR VELOCITY $V = Q / A$

- TOTAL PRESSURE : $P_t = P_s + P_v$

- VELOCITY PRESSURE : $P_v = (V /4.04)^2$ mm wg for metric, $P_v = (V / 4009)^2$ in wg for FPS

  FAN OUTPUT POWER(TOTAL) : $= P_t \times Q \times 9.81 / 1000$ kW for metric
  $Ho = P_t \times Q /6360$ hp for FPS

  FAN OUTPUT POWER (STATIC) : $Ho_s = Ps \times Q \times 9.81 /1000$ kW for metric,
  $Ho_s = Ps \times Q \times 9.81 /6360$ hp for FPS

- TOTAL EFFICIENCY % : $\eta_t = (Ho / Hi \times 100)$

- STATIC EFFICIENCY% : $\eta_S = (Ho_S / Hi) \times 100$

- TIP SPEED : $T_S = (\pi \times D \times N) / 60$ m/s for metric, $T_S = \pi \times D \times N$ ft/min for FPS

- NET FREE AREA : $A = \pi / 4 (D^2 – d^2)$

- SOLIDITY RATIO = SUM OF FAN BLADE TIP CHORDS / ($\pi \times D$)

…. 06. USEFUL FORMULAS & FAN LAWS

B. BASIC FAN LAWS

❖ Effect of Fan Speed

a. FAN AIR FLOW RATE VARIES DIRECTLY WITH FAN SPEED RATIO:

b. Q2 = Q1 x (N2/N1)2

c. FAN PRESSURE VARIES WITH THE SQUARE OF FAN SPEED RATIO:

d. P2 = P1 x (N2/N1) 2

e. FAN INPUT POWER VARIES WITH CUBE OF FAN SPEED RATIO :

f. H2 = H1 x (N2/N1) 3

❖ Effect of Air Density

a. AIR FLOW RATE REMAINS THE SAME WITH A CHANGE IN AIR DENSITY

b. PRESSURE VARIES IN PROPORTION TO THE AIR DENSITY

c. P2 = P1 x (ρ2/ρ1)

d. FAN INPUT POWER VARIES IN PROPORTION TO THE AIR DENSITY

e. H2 = H1 x (ρ2/ρ1)