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Revision Memo

12/01	Page 5 Updated information on axial fans efficiency and low noise blading. Page 7 Updated coupling shafting and fan blades material of construction and preferences.
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SCOPE

This section presents a general introduction to the application of fans for process plant services, complementing the more specific coverage of [Section VIII-G, Forced-Draft Systems](#).

REFERENCES

DESIGN PRACTICES (BESIDES OTHER SECTIONS OF SECTION XI)

Section VIII	Fired Heaters
Section IX	Heat Exchange Equipment

GLOBAL PRACTICES

GP 6-4-1	Air-Cooled Heat Exchangers
GP 8-1-1	Cooling Towers
GP 10-11-1	Sizing of Drivers and Transmissions for Compressors, Fans, and Pumps
GP 10-13-1	Special Purpose Centrifugal Fans
GP 10-13-2	General Purpose Centrifugal Fans

OTHER REFERENCES

API 661, *Air Cooled Heat Exchangers for General Refinery Services*.

API 673, *Special Purpose Centrifugal Fans for General Refinery Service*.

Kenny, R. J., *Fans and Blowers*, Machine Design, March 14, 1968.

Baumeister, T., *Mechanical Engineer's Handbook*, Subsection on Centrifugal and Axial Fans, McGraw-Hill.

Osborne, W. C., *Fans*, Pergamon Press, Oxford, 1966.

ASHRAE *Guide and Data Book*, 1969 Equipment Volume, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

DEFINITIONS

The nomenclature and definitions presented here are those conventionally used in the fan engineering field. They are somewhat different from the symbols and definitions commonly applied to compression service and process plant design and are presented here as a convenient reference for the process designer. See [Section XI-A, Compression Service Design Procedures](#) for normal compression service nomenclature. See [Section VIII](#) for fired heater system design nomenclature.

Total Pressure (Pt) - In a flowing gas system total pressure at a particular point is the sum of the static and velocity pressures at that point. See [Figure 1](#).

$$P_t = P_s + P_v$$

Fan Total Pressure (FTP) - The rise in total pressure from the fan inlet to the fan outlet. It is measured by the differential reading between impact tubes facing the gas flow in the fan inlet and discharge ducts (at the fan flanges). For a fan handling atmospheric air with no inlet duct, total pressure on the inlet side, P_t , is zero (gage) and P_t at the discharge flange = FTP. Total pressure of a fan, like the head of a compressor, is the measure of energy increase imparted by the fan to the flowing gas but on a per unit volume, rather than a per unit mass, basis.

Fan Velocity Pressure (FVP) - The pressure due to the average velocity through the fan outlet V_{m2} .

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DEFINITIONS (Cont)

$$\text{FVP, in. of water} = \frac{\rho (V_{m2})^2}{1.203 \times 10^6}$$

where: ρ = Density of gas at fan outlet, lb/ft³
 V_{m2} = Q/A , ft/min.
 Q = Actual ft³/min. at outlet conditions
 A = Cross-sectional area at fan outlet, ft²
 For standard air @ 70°F, $\rho = 0.075$ lb/ft³ and $\text{FVP} = (V_{m2} / 4005)^2$

or

$$\text{FVP, mm of water} = 5.115 \times 10^{-2} \rho (V_{m2})^2$$

where: ρ = Density of gas at fan outlet, kg/m³
 V_{m2} = Q/A , m/s
 Q = Actual m³/s at outlet conditions
 A = Cross-sectional area at fan outlet, m²
 For standard air @ 20°C, $\rho = 1.2014$ kg/m³ and $\text{FVP} = 6.14 \times 10^{-2} (V_{m2})^2$

The FVP is indicated by differential reading between an impact tube facing the direction of flow in the fan outlet and a static reading normal to flow in the fan outlet.

Fan Static Pressure (FSP) - The total pressure rise minus the fan outlet velocity pressure. Static pressure is indicated by the differential reading of an impact tube facing the direction of flow in the fan inlet, and a static reading normal to the flow in the fan outlet.

Standard Air Density - 0.075 lb/ft³ (1.2014 kg/m³) corresponding to an ambient temperature of 70°F (20°C) and ambient pressure of 14.7 psia (1.013 bara).

Actual air density can be evaluated in terms of ambient conditions by:

$$\rho = \frac{2.697 P_B}{T} \text{ lb/ft}^3$$

where: P_B = Barometric pressure in psia
 T = Temperature, °R

or

$$\rho = \frac{352 P_B}{T} \text{ kg/m}^3$$

where: P_B = Barometric pressure in bara
 T = Temperature, K

OTHER TERMS

The unit of pressure is 1 in. (1 mm) of water column [water density of 62.3 lb/ft³ (1000 kg/m³)].

The volume (flow rate) handled by a fan is the number of ft³ of air per minute or cubic meters per second expressed at fan outlet conditions.



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DEFINITIONS (Cont)

The **power output** of a fan is the power supplied to the air stream and is termed air power. It is based on fan volume and fan total pressure:

$$\text{Air Horsepower or Fan Power Output} = (1.57 \times 10^{-4}) P_t Q$$

where: Q = Actual ft³/min
 P_t = Total pressure in in. of water

or

$$\text{Air Power kW or Fan Power Output} = (9.8 \times 10^{-3}) P_t Q$$

where: Q = Actual m³/sec
 P_t = Total pressure in mm of water

Static Pressure Power - In many fan services the fan velocity pressure is wasted (i.e., not converted efficiently) and only the static pressure is useful. Static pressure, P_s , can be substituted for P_t to obtain the static pressure power.

Power input to a fan is the horsepower delivered to the fan shaft.

Fan mechanical efficiency e_m , the ratio of power output to power input.

Fan static efficiency e_s , the mechanical efficiency multiplied by the ratio of the static pressure to the total pressure:

$$\text{BHP or kW} = \frac{\text{air power}}{e_m} = \frac{\text{static pressure power}}{e_s}$$

BACKGROUND

Fans are dynamic gas moving machines designed for very low pressure rise and high volume flow rates. They employ impeller tip speeds in the 70 ft/sec (20 m/sec) to 600 ft/sec (180 m/sec) range, most models being limited to 200 ft/sec (60 m/sec) to 250 ft/sec (75 m/sec). Centrifugal compressors, in contrast, typically operate at tip speeds of 700 to 1000 ft/sec (200 to 300 m/sec). The demarcation between "fans" and "compressors" is arbitrary and has been placed at a density increase of 7% by ASME test codes corresponding to a pressure ratio of about 1.1 or a pressure rise of 40 in. (1000 mm) of water for atmospheric air.

Global Practices covering centrifugal fans are **GP 10-13-1, Special Purpose Centrifugal Fans** and **GP 10-13-1, General Purpose Centrifugal Fans**. General purpose centrifugal fans are usually spared, are relatively small in size, and are used in non-critical services.

The Global Practices use a pressure ratio of 1.3 or lower to define their applicability. This limit is arbitrary, but is made to cover those machines not covered by **GP 10-3-1, Centrifugal Process Compressors**.

The field between $r = 1.1$ and $r = 1.3$ is covered by a loosely-defined machine type generally referred to as "pressure blowers." These are covered by centrifugal fan GP's because their construction style is similar to that of fans.

BASIC DESIGN CONSIDERATIONS

PERFORMANCE

Performance Curves - See **Figure 2** for typical performance curve shapes of the commonly used fan types.

Fan Laws - Fan Performance can be estimated for points other than the normal flow and speed point by use of the fan laws. For a given fan these laws are: (1) Volume varies directly with speed (2) pressure rise varies with the square of speed and directly as the density, and (3) power varies as the cube of speed and directly as the density.

$$(1) \quad \frac{Q_2}{Q_1} = \frac{N_2}{N_1}$$

$$(2) \quad \frac{P_2}{P_1} = \left(\frac{N_2}{N_1} \right)^2$$

$$(3) \quad \frac{GHP_2}{GHP_1} = \left(\frac{N_2}{N_1} \right)^3$$