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Industrial Process/Power Generation Fans: Specification Guidelines



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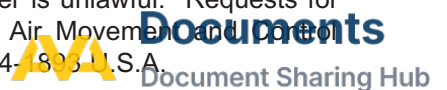
Industrial Process/Power Generation Fans: Specification Guidelines



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RELATED AMCA STANDARDS

For Air Performance:

ANSI/AMCA Standard 210	<i>Laboratory Method of Testing Fans for Aerodynamic Performance Rating</i>
AMCA Standard 803	<i>Industrial Process/Power Generation Fans: Site Performance Test Standard</i>

For Sound:

AMCA Standard 300	<i>Reverberant Room Method for Sound Testing of Fans</i>
AMCA Standard 301	<i>Methods for Calculating Fan Sound Ratings from Laboratory Test Data</i>

For Balance and Vibration:

ANSI/AMCA Standard 204	<i>Balance Quality and Vibration Levels for Fans</i>
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Industrial Process / Power Generation Series:

AMCA Publication 801	<i>Industrial Process/Power Generation Fans: Specification Guidelines</i>
AMCA Publication 802	<i>Industrial Process/Power Generation Fans: Establishing Performance Using Laboratory Models</i>
AMCA Standard 803	<i>Industrial Process/Power Generation Fans: Site Performance Test Standard</i>

Fan Application Manual:

AMCA Publication 200	<i>Air Systems</i>
AMCA Publication 201	<i>Fans and Systems</i>
AMCA Publication 202	<i>Troubleshooting</i>
AMCA Publication 203	<i>Field Performance Measurement of Fan Systems</i>

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INDEX BY FAN APPLICATION

The following is a list of common industrial fan applications that includes types of fans typically employed, major design considerations, and corresponding sections of this document. Users of this publication can employ this table as a guideline for specific applications as well as an index to related topics.

KEY TO FAN TYPES:

AF = airfoil
 BC = backward curved
 BI = backward inclined
 FC = forward curved
 PW = paddle wheel
 RT = radial tip
 VA = vaneaxial

INDUSTRIAL PROCESS FANS

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
A. CLEAN AIR, SUPPLY, and GENERAL VENTILATION	BI/BC AF VA FC Radial blade	Sound Efficiency Means of control Indoor, outdoor	4.2.8; 8 (all) 5 (all) 4.2.2-5
B. CONVEYING MATERIAL	Radial blade PW	Durability-impact on impeller, shaft, bearings Capture velocities, Entrainment velocity, Equivalent density, (includes material conveyed) Wear Build up Leakage from housing & around shaft	3.2 (all) 3.1.9-10 3.3.6-12; 4.2.7; 6 (all) 6 (all); esp. 6.2 3.3.3; 7 (all)
C. HOT GAS RECIRCULATION "DRYERS" <540°C (1000°F)	All	Spark resistance, dependent upon material Temperature Rate of temperature change Sealing and leakage Bearing cooling & lubrication Insulation Durability Method of support & materials of construction	3.2.13; 3.3.2 3.2.13; 3.3.2 3.3.3; 7 (all) 3.3.2; 7.3.8; 7.6.4

INDUSTRIAL PROCESS FANS

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
D. GENERAL EXHAUST HOODS	All	Wear Corrosion Sealing Noise Temperature Toxicity	3.3.6-12; 4.2.7; 6 (all) 6 (all) 7 (all) 4.2.8; 8 (all) 3.2.13; 3.3.2 6.1
E. CORROSIVE FUME/GAS/ODOR CONTROL	All	Corrosion Seal Material Paint Coatings Spark resistance Explosion resistance Air density High tip speed Noise Build-up	6.1 3.3.3; 7.3 6.1-2 7.6.1 3.1.9-10 8 (all) 6.2
F. AIR CLEANING SCRUBBER BOOSTER FAN BAG HOUSE FAN	AF, BI/BC (clean air) RT, PW (dirty gas)	Air density High tip speed Noise Build-up High pressure Wear & corrosion	3.1.9-10 8 (all) 6.2 3.3.6-12; 6.1
G. PELLETIZING/ SINTERING	BI/BC (limited appl.) Radial blade RT VA (sinter cooling)	Wear (severe) High temperature Rate of temperature change Build up Vibration	3.3.6-12; 6.1 3.2.13 3.2.13 6.2 3.2.11

INDUSTRIAL PROCESS FANS

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
H. MINING AND TUNNEL	VA AF BI/BC	Efficiency Sound Reliability Flow reversal Explosion resistance Spark resistance Corrosion Wear Mine safety & government reg.	4.2.8; 8 (all) 7.6.1 6.1 3.3.6-12; 6.2
I. EXPLOSIVE GAS	All	Spark resistance Explosion doors and protection Leakage-housing & shaft Corrosion	7.6.1 7.1-5 6.1
J. INCINERATION	Radial blade BI/BC AF (Depends on material being burned)	Air composition Wear Toxic gas High Temperature Rate of temperature change Sound (residential areas) High tip speed construction Leakage Sealing Reliability	3.3.6-12; 4.2.7; 6.1 3.2.13; 3.3.2 3.2.13; 3.3.2 4.2.8; 8 (all) 7.1-7.6 7.1-7.6
K. BASIC OXYGEN (System operates at shut off and periodically goes to full flow)	Radial blade BI/BC	Non-surge & stability over range of operation Gas tightness High tip speed construction Starts and stops Wear (water erosion) Build up Corrosion	5 (all) 7.1-7.6 9.3.6 3.3.6-12; 4.2.7; 6.1 6.2 6.1

Industrial Process Fans

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
L. HOT GAS EXHAUST (Coal Drying Kiln)	All	Duty cycle Build up Wear High temperature Rate of temperature change	6.2 3.3.6-12; 4.2.7; 6.1 3.2.13; 3.3.2 3.2.13; 3.3.2
M. HIGH PRESSURE BLOWERS (Combustion air)	Radial blade BI/BC AF	High tip speed construction Bearing thrust & max. bearing speed Leakage and seals Air Dynamics: Mach number, compressibility, regain, noise Stability-turn down ratio	3.3.5 7.1-6 5 (all)
N. HIGH TEMPERATURE FANS >540°C (1000°F)	All	Thermal expansion Structural integrity Bearings-cooling & lubrication Materials of construction Insulation Corrosion	3.2.13; 3.3.2 3.3.5 6.1
O. BRAKE FAN (Power absorption fan) Absorb power in spillways, etc. when dropping gates.	BI/BC (running backwards) FC	High power (for volume and pressure)	
P. FOOD & TEXTILE (Smooth finish fan)	AF BI/BC Radial blade	Super smooth finish Stainless construction	7.6.2

POWER GENERATION FANS

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
A. FORCED DRAFT (FD)	AF	Efficiency & operating point	3.1.13-16
1. Supplies combustion air to a boiler	BI/BC FC VA	Means of control-turndown & leakage	4.2
2. Provides excess air for complete combustion.		Indoor/outdoor operation	9.3.6
3. Overcomes losses from fan to balance draft point in boiler.		Sound	8.4.2.8
		Reliability (mechanical)	3.2 (all); 13 (all)
		Stress analysis & structural specs	3.2 (all); 13 (all)
		Quality assurance programs	10; (all)
B. INDUCED DRAFT (ID)	AF	Same as FD +	See A, above, plus:
1. Exhausts products of combustion	BI/BC FC VA RT	Air analysis & density	3.1.9-10
2. Exhausts excess air		Corrosion	6 (all)
3. Provides necessary draft at fire and overcomes losses to the end of the system minus any natural draft.		Wear	3.3.6-12; 4.2.7; 6 (all)
		Turning gear	3.3.1
		Maximum temperature	3.2.13; 3.3.2
		Rate of temperature change	3.2.13; 3.3.2
		Leakage-housing & seals	3.3.3; 7 (all)
		Means of support for thermal expansion	3.3.2; 7.6.4; 9.3.8
C. PRIMARY AIR HOT	AF	Same as FD +	See A, above, plus:
1. Transports powdered fuel from pulverizer to burner.	BI/BC Radial blade	Temperature	3.2.13
2. Provides some combustion air.		Wear	6 (all)
3. Makes up for some leakage out of the boiler.		Leakage-housing & seals	7 (all)
4. Takes air after air heater and fan overcomes losses in transporting fuel plus air losses minus energy from the FD fan.			
COLD			
1. Air is taken from ambient sources.	VA		
2. See HOT #1 through #3 above.			

POWER GENERATION FANS

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
D. FLUIDIZED BED BOILER 1. Provides some combustion air. 2. Floats bed	AF BI/BC Radial blade	Very high pressure High stress High fixed resistance	5 (all) 3.2 (all) 5 (all)
E. GAS RECIRCULATION 1. Redirects boiler gases increasing mass flow through various parts of the furnace, superheaters, reheaters, economizers. 2. Tempers hot gases in the boiler to 1040°C (1900°F). 3. Overcomes losses though boiler passages & the recirculation ductwork.	AF BI/BC RT	Same as I.D. + Shut off pressure considerations Leakage-housing & seals	See B, above, plus: 5 (all) 3.3.3; 7 (all)
F. OVERFIRE AIR 1. Delivers air over the fire to improve combustion and reduce smoking. 2. Reduced FD requirements, overcomes piping losses and provides turbulent mixing action.	AF BI/BC	Same as FD	See A, above

POWER GENERATION FANS

Application	Typical Fan Employed	Usual Major Consideration	Applicable 801 Section
G. FLUE GAS DESULFURIZATION (FGD) BOOSTER In series with ID fan to provide added pressure capability to overcome air pollution devices in retrofit application.	Same as ID fan lower temperature	Same as ID but at	Same as B, above
H. INDIRECT REHEAT Adds clean heated air to system	Same as FD	Same as FD	Same as A, above.
I. SECONDARY AIR Provides additional combustion air	Same as FD	Same as FD	Same as A, above
J. CYCLONE BURNER Provides combustion air plus energy to produce cyclonic action in burner and furnace.	Same as FD	Same as FD	Same as A, above
K. SEAL AIR 1. Provides clean air to chamber surrounding furnace 2. Creates pressure large enough to prevent the escape of dirty gas from the furnace and any auxiliary (dampers, etc.)	AF, BI/BC	Same as FD	Similar to those listed under A
L. WASTE ENERGY FAN 1. Takes hot gases including waste from waste heat boiler.	Same as ID	Build up Clogging of parts	6 (all)

Industrial Process/Power Generation Fans: Specification Guidelines

1. Purpose

The purpose of this publication is to familiarize the reader with the practices fan manufacturers follow in the specification of fan equipment, and to provide application information. Good communication will be ensured if recommendations given herein are followed.

There are numerous fan manufacturers supplying equipment to industry throughout the world. Due to differences in rating and proposal practices among fan manufacturers, it is vitally important that the consulting engineer, system designer, and the user thoroughly understand all fan-related concepts. Conversely, it is the responsibility of the fan manufacturers to explain these practices and, if possible, develop a common method of presenting information that will aid in making a proper equipment evaluation. This will ensure a more systematic approach to the testing, rating, specification, and construction of industrial process and power generation fans.

2. Scope

This publication provides information on testing and rating industrial process and power generation fans, and covers construction features and related appurtenances. Sample equipment specifications are included which outline information a fan manufacturer requires to select the best fan for an application. Common fan industry practices are also defined and explained.

3. Terminology

The following list of terms and their related symbols will be applied to testing, rating, specifications, and construction of industrial process and power generation fans. To avoid confusion and misunderstanding, this terminology should be used.

3.1 Rating criteria

3.1.1 Fan. A fan is a device that utilizes a power-driven rotating impeller for moving air and has at least one inlet opening and one outlet opening. The

openings may or may not have elements for connection to ductwork. A fan may have various appurtenances that affect aerodynamic performance. It is necessary to establish which appurtenances are to be considered part of the fan.

3.1.2 Fan inlet. The plane perpendicular to the airstream where it first meets the inlet cone, the inlet box or other appurtenances furnished by the fan manufacturer. In this publication, the fan inlet is indicated by "Plane 1". (See Figures 15.4 and 15.5.)

3.1.3 Fan outlet. The plane perpendicular to the airstream at the outlet opening of the fan, the outlet opening at the evasé or diffuser or other appurtenances furnished by the fan manufacturer. In this publication, the fan outlet is indicated by "Plane 2". (See Figures 15.4 and 15.5.)

3.1.4 Air. A mixture of gases; also, a term commonly used to denote any gaseous medium measured, moved or controlled and which may include solid or liquid particulate.

3.1.5 Fan airflow rate. The volumetric airflow rate at fan air density at the fan inlet.

3.1.6 Total pressure. The air pressure that exists by virtue of the degree of compression and the rate of motion. It is the algebraic sum of the velocity pressure and the static pressure at a point.

3.1.7 Velocity pressure. The portion of the air pressure that exists by virtue of the rate of motion only. It is always positive.

3.1.8 Static pressure. The portion of the air pressure that exists by virtue of the degree of compression only. It may be positive or negative relative to the ambient atmospheric pressure.

3.1.9 Fan pressure relationships and interpretations. The definitions of total pressure, velocity pressure, and static pressure are presented in Sections 3.1.6 to 3.1.8. However, when applying these definitions to fan performance, there are distinct relationships that exist between each variable. This section describes these relationships.

3.1.9.1 Fan total pressure (P_t). The difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

$$P_t = P_{t2} - P_{t1}$$

3.1.9.2 Fan velocity pressure (P_v). The pressure corresponding to the average velocity at the fan outlet area.

$$P_v = P_{v2}$$

3.1.9.3 Fan static pressure (P_s). The difference between the fan total pressure and the fan velocity pressure. Therefore, the fan static pressure is the difference between the static pressure at the fan outlet and the total pressure at the fan inlet.

$$\begin{aligned} P_s &= P_t - P_v \\ &= P_{t2} - P_{t1} - P_{v2} \\ &= (P_{s2} + P_{v2}) - P_{t1} - P_{v2} \\ &= P_{s2} - P_{t1} \end{aligned}$$

3.1.9.4 Fan static pressure rise (ΔP_s). The static pressure at the fan outlet minus the static pressure at the fan inlet. Fan static pressure rise is often mistaken for fan static pressure.

$$\Delta P_s = P_{s2} - P_{s1}$$

It can be shown that the difference between fan static pressure and static pressure rise is the inlet velocity pressure.

$$\begin{aligned} \Delta P_s - P_s &= (P_{s2} - P_{s1}) - (P_{s2} - P_{t1}) \\ &= P_{s2} - P_{s1} - P_{s2} + P_{s1} + P_{v1} \\ &= P_{v1} \end{aligned}$$

3.1.9.5 Illustration of fan pressure relationships. Fan pressure relationships are illustrated in Figure 3.1 for a fan with both inlet and outlet ducts. As can be seen, there is a distinct difference between static pressure rise and fan static pressure as defined by ANSI/AMCA 210. It should also be noted that there is a distinct difference between an entrance loss and the acceleration energy when using static pressure nomenclature. Total pressure nomenclature should be used when discussing fan aerodynamic performance; however, from past practice, static pressure terminology is still used. It is most important to recognize the interdependence between total and static pressures in a typical system.

3.1.10 Air density. The mass per unit volume of the air being handled.

3.1.11 Fan air density. The density of the air at the fan inlet. It is a function of the total pressure, temperature, and composition of the air. The fan air density affects the aerodynamic performance of a fan as outlined by the compressible fan laws contained in this publication.

3.1.12 Motor power. The power delivered from the output shaft of the motor.

3.1.13 Fan shaft power. The power delivered to the input end of the fan shaft and does not include any drive losses other than the fan bearings.

3.1.14 Maximum continuous rating (MCR) or operating point. The performance point at which the fan is normally expected to operate.

3.1.15 Test block (TB) or design point. That maximum performance point that establishes the fan selection.

3.1.16 Appurtenances. Accessories added to a fan for purposes of control, isolation, safety, static pressure regain, etc. Accessories common to fans include inlet boxes, inlet vanes, dampers, guards, motors and drives, evasés, and the like.

3.1.17 Surge limit or stall limit. The surge limit of a centrifugal fan is that point near the peak of the pressure curve that corresponds to the minimum airflow rate at which the fan can be operated without instability. The stall limit of an axial fan is that point near the peak of the pressure curve at a particular blade angle that corresponds to the minimum airflow rate at which the fan may be operated without separation of airflow over the blades. A fan must not be operated in the surge or stall region, otherwise serious damage can occur to the fan or ductwork.

3.2 Design criteria

There are a number of frequently used terms in the fan industry that may have special meanings unique to that industry. The following terminology is often encountered in fan specifications:

3.2.1 Natural frequency. The natural frequency of a structural member or system is the frequency at which it will tend to vibrate once it has been set into motion. A structure can possess many natural frequencies, each of which is associated with a mode shape of deformation. Natural frequency is normally expressed in cycles per second (Hertz).

3.2.2 First critical speed. That fan rotational speed that coincides with the lowest fundamental natural frequency of the fan shaft in bending, when the shaft is mounted in the impeller and is assumed to be supported on infinitely stiff supports at the bearing locations.

First Critical speed is normally used to provide an assessment of the adequacy of the shaft stiffness. Any effects due to gyroscopic stiffening must be

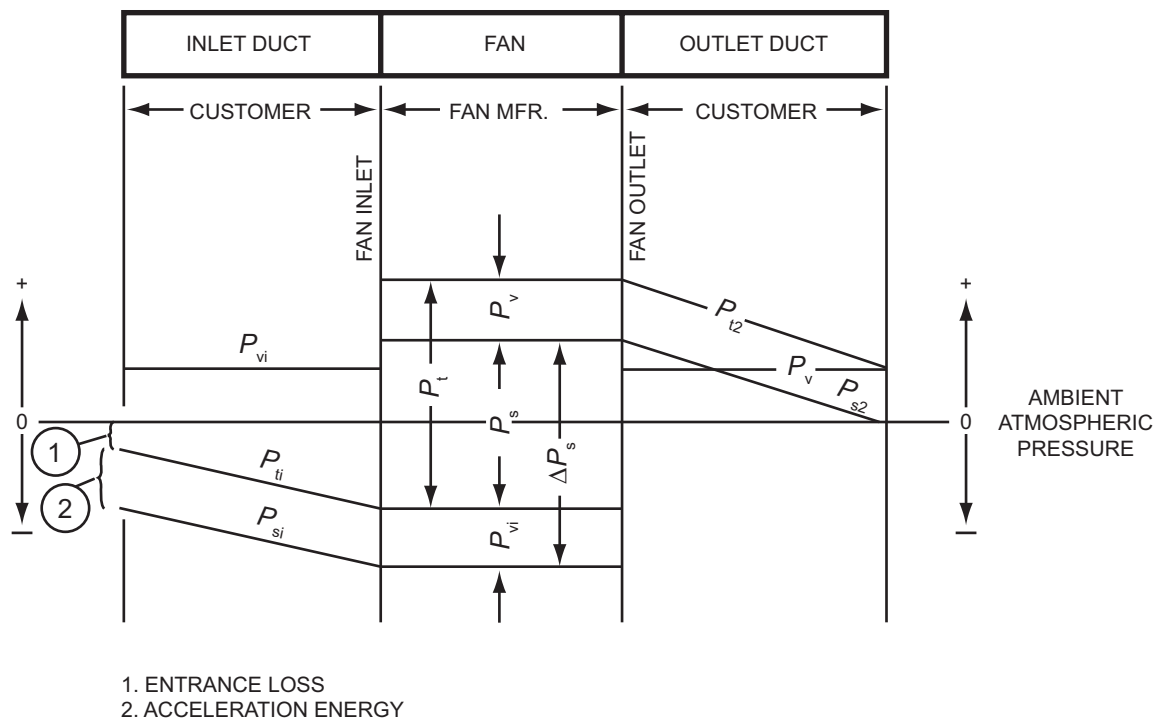


Figure 3.1 - Interpretation of Fan Pressures for Rating Purposes

agreed upon between the customer and the fan manufacturer.

3.2.3 Design resonant speed. That rotational speed which coincides with the lowest fundamental natural frequency of the fan shaft in bending when the shaft is mounted in the impeller and the stiffness of the bearing oil film, bearing housing, and bearing support is taken into account in the calculation. Oil film damping may be included if desired. The foundation is excluded from design resonant speed calculations and is assumed to be infinitely stiff.

Design resonant speed is normally used to provide an assessment of the adequacy of the system of assembled parts within the scope of the fan manufacturer's supply.

3.2.4 Installed resonant speed. That fan rotational speed which coincides with the lowest fundamental natural frequency of the fan shaft in bending when the shaft is mounted in the impeller and the stiffness of the total support system including bearing oil film, bearing housing, bearing supports, foundation, and sub-soil are taken into account. Damping values for the oil film, foundation and sub-soil may also be included if desired.

Installed resonant speed is normally used to provide an assessment of the adequacy of the total system of assembled parts, including parts not within the scope of the fan manufacturer's supply. It is normally the

customer's responsibility to ensure the foundation meets the criteria used for the calculation.

3.2.5 Foundation stiffness. Generally assumed to be the lateral spring constant of the foundation when referred to the bearing centerline. This stiffness includes the effect of the foundation block, the sub-soil beneath it, piles (if any), the concrete piers supporting the steel fan supports, and the interface between the steel supports and the concrete piers.

If a more complex foundation analysis is required which takes into account horizontal and rocking stiffness also, then this requirement must be specified.

3.2.6 Finite element stress analysis (FEA). An analytical technique that employs computer software to divide a rotating body into many segments (elements) to determine the steady state stress at each element in the body due to its rotation.

3.2.7 Finite element modal analysis (FEMA). An analytical technique that employs finite element technology to determine the fundamental motions (modes) of a rotating body and the natural frequency associated with each mode.

3.2.8 Low cycle fatigue analysis. An analytical technique that predicts the low cycle fatigue life of a rotating body (cycles to crack initiation) based on the steady state stress at each point as determined by FEA or other means.

3.2.9 Fracture mechanics analysis. An analytical technique which predicts the number of cycles from crack initiation to failure of a rotating body (critical flaw size).

3.2.10 Torsional critical speed. The fan rotational speed which corresponds to the natural frequency of the entire driver and driven rotor system in a torsional mode.

3.2.11 Seismic requirements. A seismic force involves a dynamic force at a particular frequency and duration. Due to the difficulty in defining these parameters and the complexity of the analysis, it is recommended that a static analysis be performed for the fan impeller and housing or casing in place of any seismic analysis. The static load will consist of a horizontal force applied both in the axial and transverse direction to the shaft. The forces will be applied at the bearings and at the center of the housing to determine the adequacy of the anchor bolts

3.2.12 Temperature. One cause of premature fan failure is the lowering of the strength of a fan material by handling air or gas at a higher temperature than specified. In addition, fan performance is significantly affected by temperature. It is, therefore, very important to understand the following four definitions:

3.2.12.1 Peak design temperature. The maximum temperature at which a fan can operate for a specific duration of time.

3.2.12.2 Design temperature. The maximum gas temperature at which a fan can be continually operated.

3.2.12.3 Operating temperature. The gas temperature in the fan during normal conditions.

3.2.12.4 Rate of temperature change. The increase or decrease in temperature in a specified time interval. If air temperatures in the fan fluctuate, there is a possibility of vibration due to uneven rates of expansion between various parts of the fan. The fan manufacturer should be consulted if temperature swings are anticipated.

3.2.13 Interference fit. A fit between the impeller hub and the rotating shaft having limits of size so specified that an interference always results when mating parts are assembled; the fit may be either a press fit or a shrink fit.

3.3 Special features

3.3.1 Turning gear. An assembly consisting of a

motor, a speed reducer, and a uni-directional engagement clutch fastened to the outboard end of the fan shaft or motor shaft through a flexible coupling. The turning gear rotates the complete rotating assembly at a low speed when a hot fan is taken out of service to prevent distortion from developing in the impeller and shaft assembly due to uneven cooling. The turning gear may be sized to start the fan and main motor from rest to reduce the starting requirements on the main drive motor. Axial fans generally do not require this feature. The type of turning gear should be specified.

3.3.2 Centerline support. Support of the fan housing at the fan centerline when necessary to reduce differential thermal growth.

3.3.3 Shaft seal. A device that limits leakage between the shaft and fan housing. There are many different designs available depending upon the requirements.

3.3.4 Expansion joints. A flexible member used to attach the fan inlet and/or outlet to connecting ductwork. Expansion joints are available in a variety of materials including elastomers, metals and various composite fabrics, depending on the temperature, pressure and constituents of the gas being handled. Expansion joints on the fan inlet and discharge should be employed whenever possible to reduce transmission of vibration from the fan to its associated ductwork and to isolate the fan from any external loads which could be applied from the ductwork. Expansion joints should also be used on any fan mounted on vibration isolators. Unless specified otherwise, fans will not be designed to withstand external loads.

3.3.5 Bearings. Bearings are among the most critical mechanical components of a fan and are selected to handle radial and thrust loads produced during fan operation. The following comments are to be used only as a general guide. Bearings can be classified in two general categories: journal (sleeve) and anti-friction.

Generally, journal bearings handle moderate to heavy loads over a wide speed range. They have split construction, are oil lubricated, and have theoretically infinite life with proper maintenance. Cooling is possible via water, air, or circulating oil.

The two primary types of anti-friction bearings are further classified as ball bearings or roller bearings. Compared to journal bearings, anti-friction bearings have lower initial cost and have a finite service life. Ball bearings are for high speed, light load, low to moderately high temperature applications. Grease is the usual lubricant. External cooling is not applicable.