Centrifugal Fans for Petroleum, Chemical, and Gas Industry Services

API STANDARD 673
THIRD EDITION, DECEMBER 2014

AMERICAN PETROLEUM INSTITUTE

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Users of this Standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the specification.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Contents

Contents

Introduction

Users of this standard should be aware that further or different requirements may be needed for individual applications. This standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this standard and provide details.

This standard requires the purchaser to specify certain details and features. A bullet (•) at the beginning of a paragraph indicates that either a decision by, or further information from, the purchaser is required. Further information should be shown on the datasheets (see Annex A) or stated in the quotation request and purchase order.

Centrifugal Fans for Petroleum, Chemical, and Gas Industry Services

1 Scope

1.1 This standard covers the minimum requirements for centrifugal fans for use in petroleum, chemical, and gas industry services. Fan static pressure rise is limited to differential usually not exceeding 130 in. (330 cm) of water equivalent air pressure from a single impeller or each impeller in a two stage fan. This standard does not apply to axial flow, aerial cooler, cooling tower, and ventilation fans and positive displacement blowers.

• **1.2** This standard covers equipment for both general purpose and special purpose applications. The purchaser shall determine which classification applies.

NOTE Refer to Section 3 for definition of the terms general purpose and special purpose.

1.3 Additional or overriding requirements applicable to special purpose applications are included at the end of each section (e.g. 6.7.5, etc.).

2 Normative References

2.1 The editions of the following standards, codes, and specifications that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this standard. The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the purchaser and vendor.

API Specification 5L, *Specification for Line Pipe*, Forty-Fifth Edition

API Recommended Practice 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2*, Second Edition

API Standard 541, *Form-wound Squirrel-cage Induction Motors—500 Horsepower and Larger*, Fourth Edition

API Standard 546, *Brushless Synchronous Machines—500 kVA and Larger*, Third Edition

API Standard 547, *General-purpose Form-wound Squirrel Cage Induction Motors 250 Horsepower and Larger*, First Edition

API Recommended Practice 578, *Material Verification Program for New and Existing Alloy Piping Systems*, Second Edition

API Standard 611, *General-purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*, Fifth Edition

API Standard 612, *Petroleum, Petrochemical and Natural Gas Industries—Steam Turbines—Special-Purpose Applications*, Sixth Edition

API Standard 613, *Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services*, Fifth Edition

API Standard 614, *Lubrication, Shaft-sealing, and Control-oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services*, Fifth Edition

API Standard 670, *Machinery Protection Systems*, Fourth Edition

API Standard 671, *Special-purpose Couplings for Petroleum, Chemical, and Gas Industry Services*, Fourth Edition

API Standard 677, *General-purpose Gear Units for Petroleum, Chemical and Gas Industry Services*, Third Edition

API Recommended Practice 684, *Paragraphs Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals and Rotor Balancing*, Second Edition

API Recommended Practice 686, *Recommended Practices for Machinery Installation and Installation Design*, Second Edition

ABMA Standard 7 [1], *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plan*

ABMA Standard 8.1:1986, *Ball and Roller Bearing Mounting Accessories, Metric Design*

ABMA Standard 8.2:1999 (R2008), *Ball and Roller Bearing Mounting Accessories, Inch Design*

ABMA Standard 9:1990 (R2008), *Load Ratings and Fatigue Life for Ball Bearings*

ABMA Standard 19.1:2011, *Tapered Roller Bearings—Radial Metric Design*

ABMA Standard 19.2:1994 (R2008), *Tapered Roller Bearings—Radial Inch Design*

ABMA Standard 20:2011, *Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types Metric Design*

AGMA 9000:2011 [2], *Flexible Couplings—Potential Unbalance Classification*

AGMA 9002:2004 (R2011), *Bores and Keyways for Flexible Couplings (Inch Series)*

AMCA Standard 99-10 [3], *Standards Handbook*

AMCA Standard 99-2404-03, *Drive Arrangements for Centrifugal Fans*

AMCA Standard 201-02 (R2011), *Fans and Systems*

AMCA Publication 203-90 (R2011), *Field Performance Measurement of Fan Systems*

AMCA Standard 210-99 (R2007), *Laboratory Methods of Testing Fans for Rating*

AMCA Publication 801-01 (R2008), *Industrial Process/Power Generation Fans: Specification Guidelines*

AMCA Publication 802-02 (R2008), *Industrial Process/Power Generation Fans: Establishing Performance Using Laboratory Models*

AMCA Standard 803-02 (R2008), *Industrial Process/Power Performance Fans: Site Performance Test Standard*

ANSI [4]/AWS D1.1/D1.1M:2010 [5], *Structural Welding Code—Steel*

ANSI/AWS D14.6/D14.6M:2011, *Specification for Welding of Rotating Elements of Equipment*

ASME B1.1:2003(R2008) [6], *Unified Inch Screw Threads (UN and UN and UNR Thread Form)*

ASME B1.15:1995, *Unified Inch Screw Threads (UNS Thread Form)*

---

1 American Boiler Manufacturers Association, 8221 Old Courthouse Road, Suite 207, Vienna, Virginia 22182, www.abma.com.
2 American Gear Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, Virginia 22314, www.agma.org.
3 Air Movement and Control Association, 30 West University Drive, Arlington Heights, Illinois 60004, www.amca.org.
4 American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.
5 American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.
6 ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME B1.20.1:1983 (R2006), *Pipe Threads, General Purpose (Inch)*

ASME B1.21M:1997, *Metric Screw Threads*

ASME B15.1:2000, *Safety Standard for Mechanical Power Transmission Apparatus*

ASME B16.1:2010, *Gray Iron Pipe Flanges and Flanged Fittings (Classes 25, 125, and 250)*

ASME B16.5:2013, *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24*

ASME B16.11:2011, *Forged Fittings, Socket-Welding and Threaded*

ASME B16.42:2011, *Ductile Iron Pipe Flanges and Flanged Fittings Classes 150 and 300*

ASME B16.47:2011, *Large Diameter Steel Flanges NPS 26 Through NPS 60*

ASME B17.1:1967 (R2013), *Keys and Keyseats*

ASME B31.3:2012, *Process Piping*

ASME PTC 36, *Measurement of Industrial Sound*

ASME *Boiler and Pressure Vessel Code (BPVC)*, *Section VIII: Pressure Vessels*

ASME *Boiler and Pressure Vessel Code (BPVC), Section IX: Welding and Brazing Qualifications*

ASTM A53/A53M-2012 [7], *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless*

ASTM A105/A105M-2012, *Standard Specification for aron Steel Forgings for Piping Application*

ASTM A106/A106-2011, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*

ASTM A153/A153M-2009, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ASTM A181/A181M-2012, *Standard Specification for Carbon Steel Forgings for General Service Piping*

ASTM A193/A193M-2012, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A194/A194M-2012, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature or Both*

ASTM A197/A197M-2000 (R2011), *Standard Specification for Cupola Malleable Iron*

ASTM A269-2010, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*

ASTM A312/A312M Rev A-2013, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

ASTM A338-1984 (R2009), *Standard Specification for Malleable Iron Flanges, Pipe Fittings, and Valve Parts for Railroad, Marine, and Other Heavy Duty Service at Temperatures Up To 650 Degrees F (345 Degrees C)*

---

[7] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM A388/A388M, *Standard Practice for Ultrasonic Examination of Heavy Steel Forgings*

ASTM A515/A515M:2010, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate and Higher Temperature Service*

ASTM A524-1996, *Standard Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures*

ASTM A578/A578M:2007 (R2012), *Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*

ASTM A609/A609M:2012, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

ASTM E94:2004 (R2010), *Standard Guide for Radiographic Examination*

ASTM E165:2012, *Standard Test Method for Liquid Penetrant Examination*

ASTM E709:2008, *Standard Guide for Magnetic Particle Examination*

ASTM E1003:2013, *Standard Practice for Hydrostatic Leak Testing*

EN 287:2011 [8], *Qualification Test of Welders*

EN 288:2011, *Specification and Approval of Welding Procedures for Metallic Materials*

EN 953:2009, *Safety of Machinery—Guards—General Requirements for the Design and Construction of Fixed and Movable Guards*

IEC 60034-5 [9], *Rotating electrical machines—Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP Code)—Classification*

IEC 60079, *Electrical apparatus for explosive gas mixtures*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEEE 841 [10], *Standard for Petroleum and Chemical Industry—Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 370 kW (500 hp)*

ISO 7-1:1994 [11], *Pipe threads where pressure-tight joints are made on the threads—Part 1: Dimensions, tolerances and designation*

ISO 15:1998, *Rolling bearings—Radial bearings—Boundary dimensions, general plan*

ISO 261:1998, *ISO general purpose metric screw threads*

ISO 281:2007, *Rolling bearings—Dynamic load ratings and rating life*

ISO 286-2:2010, *Geometrical product specifications (GPS)—ISO code system for tolerances on linear sizes—Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts*

---

8 European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.
9 International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.
10 Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854, www.ieee.org.
11 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

ISO 355:1977, *Metric tapered roller bearings—Flanged cups—Boundary dimensions*

ISO 492:2002, *Rolling bearings—Radial bearings—Tolerances*

ISO 582:1995, *Rolling bearings—Chamfer dimensions—Maximum values*

ISO 1940-1:2003, *Mechanical vibration—Balance quality requirements for rotors in a constant (rigid) state—Part 1: Specification and verification of balance tolerance*

ISO 3290:2001, *Rolling bearings—Balls—Dimensions and tolerances*

ISO 3448:1993, *Industrial liquid lubricants—ISO viscosity classification*

ISO 3740:2000, *Acoustics—Determination of sound power levels of noise sources—Guidelines for the use of basic standards*

ISO 3744:1994, *Acoustics—Determination of sound power levels of noise sources using sound pressure—Engineering method in an essentially free field over a reflecting plane*

ISO 3746:1995, *Acoustics—Determination of sound power levels of noise sources using sound pressure—Survey method using an enveloping measurement surface over a reflecting plane*

ISO 5753:1991, *Rolling bearings—Radial internal clearance*

ISO 5855:1999, *Aerospace—MJ threads*

ISO 6708:1995, *Pipework components—Definition and selection of DN (nominal size)*

ISO 7005-1:1992, *Metallic flanges—Part 1: Steel flanges*

ISO 7005-2:1988, *Metallic flanges—Part 2: Cast iron flanges*

ISO 8068:2006, *Lubricants, industrial oils and related products (class L) family T (turbines) specification for lubricating oils for turbines*

ISO 8501-1:1988, *Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness—Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8821:1989, *Mechanical vibration—Balancing—Shaft and fitment key convention*

ISO 10438:2003, *Petroleum, petrochemical and natural gas industries—Lubrication, shaft-sealing and control-oil systems and auxiliaries*

ISO 10441:1999, *Petroleum and natural gas industries—Flexible couplings for mechanical power transmission—Special purpose applications*

ISO 14120:2002, *Safety of machinery—Guards—General requirements for the design and construction of fixed and movable guards*

ISO 14691:1999, *Petroleum and natural gas industries—Flexible couplings for mechanical power transmission—General purpose applications*

ISO 15156-1:2009, *Petroleum and natural gas industries—Materials for use in H_2S containing environments in oil and gas production—Part 1: General principles for selection of cracking-resistant materials*

ISO 15607:2004, *Specification and qualification of welding procedures for metallic materials*

ISO 15614:2005, *Specification and qualification of welding materials*

NACE MR0103 [12], *Materials resistant to sulfide stress cracking in corrosive petroleum refining environments*

NACE MR0175/ISO 15156, *Petroleum and natural gas industries—Materials for use in H_2S-containing environments in oil and gas production—Part 1: General principles for selection of cracking-resistant materials—Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons—Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*—Item No 21306; ISO 15156-1, ISO 15156-2, ISO 15156-3; Technical Corrigendum 1:09/01/2005

NEMA SM 23 [13], *Steam Turbines for Mechanical Drive Service*

NEMA Publication 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NFPA Publication 70 [14], *National Electric Code*, *Articles 500, 501, 502, 504, and 505*

SSPC SP-6 [15]/NACE No. 3, *Commercial Blast Cleaning*, 2000

2.2 The purchaser and vendor shall mutually determine the measures required to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment.

2.3 It is the vendor's responsibility to invoke all applicable specifications to each subvendor.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
alarm point
Preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action.

3.2
anchor bolts
Bolts used to attach the equipment to the support structure (concrete foundation or steel structure).

3.3
axially split joint
Joint split with the principal face parallel to the shaft centerline.

3.4
certified point
Point to which the performance tolerances are applied.

NOTE This is usually the normal operating point and the vendor will normally require that this point is within the preferred selection range.

[12] NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.
[13] National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209, www.nema.org.
[14] National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.
[15] The Society for Protective Coatings, 40 24th Street, Sixth Floor, Pittsburg, Pennsylvania 15222, www.sspc.org.

3.5
critical speed
Shaft rotational speed at which the rotor-bearing support system is in a state of resonance.

3.6
evase
Transition piece with increasing cross-sectional area in the direction of flow at the fan discharge.

3.7
fan impeller
Assembly comprised of the blades, center plate (or back plate), shroud(s), hub, and wear plates, if used.

3.8
fan rated point
Defined as 1) the highest speed necessary to meet any specified operating condition and 2) the rated capacity required by fan designs to meet all specified operating points. (The vendor shall select this capacity point to best encompass specified operating conditions within the scope of the expected performance curve.) (See Figure 1.)

NOTE This term is NOT to be confused with the AMCA 802-02 definition of RATING point, which more nearly matches "normal point" per paragraph 3.2.5. It is suggested the user add head and/or volume margins for process uncertainties, reduced performance resulting from time related "wear and tear" and other operating conditions known to exist. The API "rated" point will be the same as the AMCA defined "MCR Test Block" (paragraph 3.1.13, AMCA 801-01) condition unless otherwise defined by the user in specifications or datasheets. For most applications this will coincide with "test block" (paragraph 3.1.14, AMCA 801-01).

3.9
fan rotor
Assembly of the fan impeller and the shaft.

3.10
forced draft fans
Usually have ambient inlet conditions and usually are in air service. This type of fan is providing ambient supply air to a unit such as fired heater for combustion air.

3.11
general purpose application
Application that is usually spared or is in noncritical service.

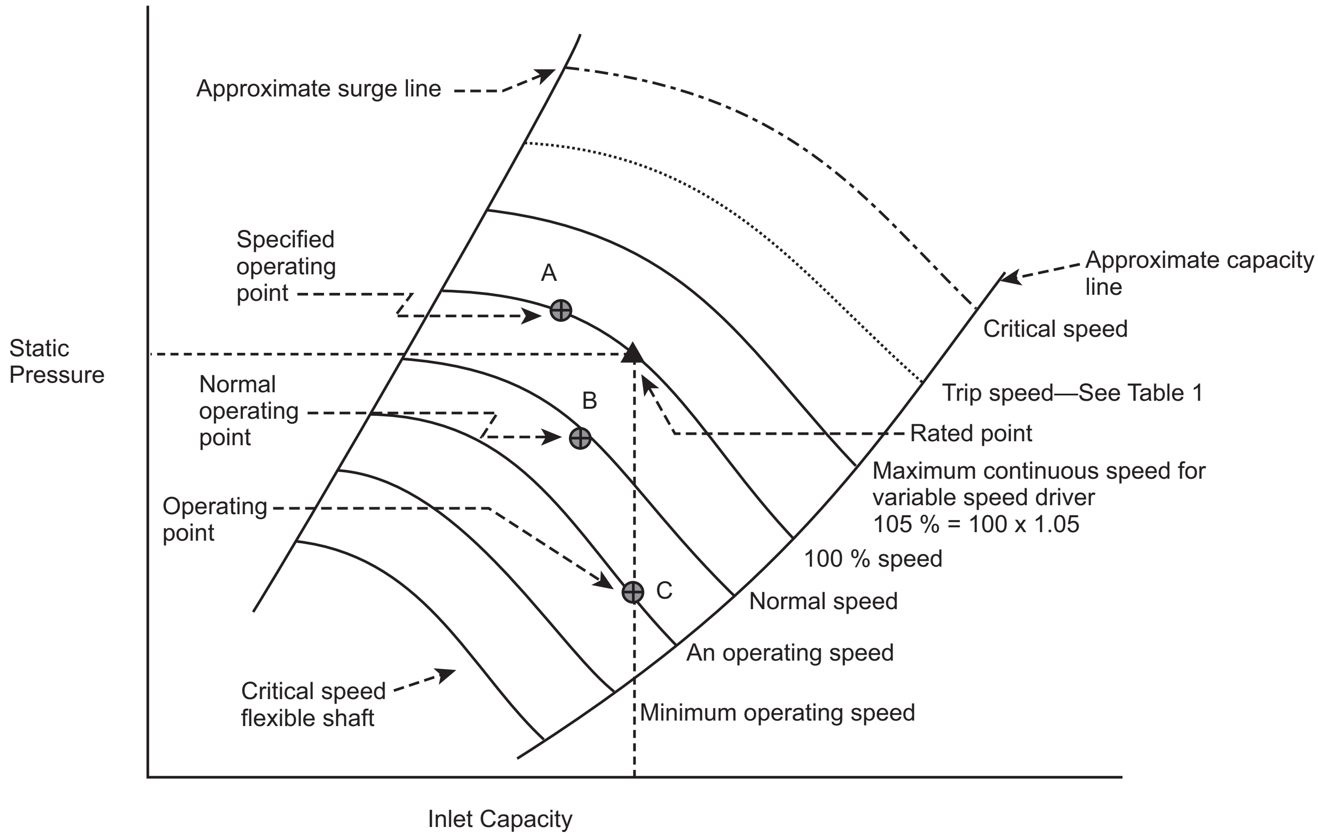
NOTE Ambient air fans such as forced draft fans may be unspared and may be deemed as general purpose.

3.12
hold-down bolts
mounting bolts
Bolts holding the equipment to the mounting plate.

3.13
hydrodynamic bearings
Bearings that use the principles of hydrodynamic lubrication.

NOTE The bearing surfaces are oriented so that relative motion forms an oil wedge, or wedges, to support the load without shaft-to-bearing contact.

3.14
induced draft fans
Usually have inlet conditions that are below atmospheric pressure and can be found in a wide variety of gas services. This type of fan is normally downstream of combustion air such as outlet of fired heater or furnace so fan air temperature is elevated.



NOTE 1 Except where specific numerical relationships are stated, the relative values implied in this figure are assumed values for illustration only.

NOTE 2 The 100 % speed curve is determined from the operating point requiring the highest static pressure; point A in the illustration.

NOTE 3 The fan rated point is the intersection on the 100 % speed curve corresponding to the highest flow of any operating point; point C in the illustration.

NOTE 4 Refer to 6.7 for discussion of critical speeds.

Figure 1—Fan Performance Terms

3.15
inlet volume flow
Flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility, and gas composition, including moisture content, at the fan inlet flange.

NOTE Inlet volume flow is a specific example of actual volume flow. Actual volume flow is the volume flow at any particular location such as interstage, impeller inlet, discharge, or fan discharge. Actual volume flow should not be used interchangeably therefore with inlet volume flow.

3.16
maximum allowable speed
Highest speed at which the manufacturer’s design will permit continuous operation.

NOTE The maximum allowable speed is usually set by rotor stress values.

3.17
maximum allowable temperature
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

3.18
maximum allowable working pressure
MAWP
Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating temperature.

3.19
maximum continuous speed
Highest rotational speed (revolutions per minute) at which the machine, as built and tested, is capable of continuous operation with the specified fluid at any of the specified operating conditions.

3.20
maximum discharge pressure
Maximum suction pressure plus the maximum differential pressure the fan is able to develop when operating within the specified operating conditions.

3.21
maximum sealing pressure
Highest pressure the seals are required to seal during any specified static or operating condition and during start-up and shutdown.

3.22
minimum allowable speed
Lowest speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

3.23
minimum allowable temperature
Lowest temperature for which the manufacturer has designed the equipment (or any part to which the term is referred).

3.24
normal operating point
Point at which usual operation is expected and optimum efficiency is desired. This point is usually the point at which the vendor certifies that performance is within the tolerances stated in this standard.

3.25
observed
Inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled even if the purchaser or his/her representative is not present.

3.26
oil mist lubrication
Lubrication systems that employ oil mist produced by atomization in a central unit and transported to the bearing housing, or housings, by compressed air.

3.27
owner
Final recipient of the equipment who may delegate another agent as the purchaser of the equipment.

3.28
purchaser
Agency that issues the order and specification to the vendor.

3.29
pure oil mist lubrication
Lubrication systems in which the mist both lubricates the bearing and purges the housing.

NOTE There is no oil level in the bearing housing when using pure oil mist lubrication (i.e. dry sump).

3.30
purge oil mist lubrication
Lubrication systems in which the mist purges the bearing housing.

NOTE 1 There is an oil level in the bearing housing when using purge oil mist lubrication and the bearing is lubricated by a conventional oil bath, flinger, or oil ring lubrication system (i.e. wet sump).

NOTE 2 The purchaser may be the owner of the plant in which the equipment is to be installed or the owner's appointed agent.

3.31
rated speed
100 % speed
Highest rotational speed (revolutions per minute) required to meet any of the specified operating conditions.

3.32
shaft cooler
heat slinger
A fan (impeller), mounted on the shaft between the seal(s) and bearings, which reduces transfer of heat from the fan interior to the bearings.

3.33
shutdown point
Preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

3.34
soleplate
Plate attached to the foundation, with a mounting surface for equipment or for a baseplate.

3.35
special purpose application
Application for which the equipment is designed for uninterrupted, continuous operation in critical service and for which there is usually no installed spare equipment.

3.36
standard volume flow
Flow rate expressed in volume flow units at standard conditions as follows.

U.S. Standard Conditions

Flow:	Standard cubic feet per minute (scfm)
	Million standard cubic feet per day (mmscfd)
Pressure:	14.7 psi
Temperature:	60 °F

ISO Standard Conditions

Flow:	Cubic meters per hour (m^3/h)
	Cubic meters per minute ($m^3/min.$)
Pressure:	1.013 bar
Temperature:	0 °C

3.37
standby
Service state in which a piece of equipment is normally idle or idling and is capable of immediate automatic or manual start-up for continuous operation.

3.38
total indicator reading
total indicated runout
TIR
Difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

NOTE For a cylindrical surface, the indicated runout implies an eccentricity equal to half the reading. For a flat face the indicated runout implies an out-of-squareness equal to the reading. If the diameter in question is not cylindrical or flat, the interpretation of the meaning of TIR is more complex and may represent ovality or surface irregularities.

3.38.1
trip speed (revolutions per minute)
Speed at which an independent emergency overspeed device operates to shut down a prime mover (see Table 1).

3.39
unit responsibility
Obligation for coordinating the documentation, delivery, and technical aspects of the equipment and all auxiliary systems included in the scope of the order.

NOTE The technical aspects to be considered include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications, and testing of components.

3.40
witnessed
Inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or the purchaser's representative is in attendance.

4 General

4.1 Unit Responsibility

The vendor who has unit responsibility shall assure that all subvendors comply with the requirements of this standard and all referenced documents.

4.2 Unit Conversion

The factors in API *MPMS* Ch. 15 were used to convert from U.S. customary (USC) to SI units. The resulting exact SI units were then rounded off.

4.3 Nomenclature

A guide to API 673 nomenclature can be found in Annex B.

5 Requirements

5.1 Dimensions

The purchaser will specify whether data, drawings, hardware (including fasteners), and equipment supplied to this standard shall use the USC or SI system of measurements.

5.2 Statutory Requirements

The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment, its packaging, and any preservatives used.

5.3 Alternative Designs

The vendor may offer alternative designs for consideration by the purchaser.

5.4 Conflicting Requirements

In case of conflict between this standard and the inquiry, the inquiry shall govern. At the time of the order, the order shall govern.

6 Design

6.1 General

• **6.1.1** The purchaser shall specify the period of uninterrupted continuous operation, during which time the equipment should not require shutdown to perform maintenance or inspection.

NOTE 1 It is realized that there are some services where this objective is easily attainable and others where it is difficult.

NOTE 2 Auxiliary system design and design of the process in which the equipment is installed are very important in meeting this objective.

NOTE 3 Section 9.2.3 requires the vendor to identify any component or maintenance requirement that would result in the need to shut down the equipment within the uninterrupted operational period.

6.1.2 The vendor shall advise in the proposal any component designed for finite life.

6.1.3 The vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.

6.1.4 The purchaser shall specify the equipment's normal operating point.

6.1.5 The equipment shall be capable of operating within the entire performance map at all specified operating conditions, as well as accommodating other conditions such as momentary surge, trip, and start-up.

6.1.6 Equipment driven by induction motors shall be rated at the actual motor speed for the load conditions.

• **6.1.7** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor having unit responsibility. The equipment furnished by the vendor shall conform to the maximum allowable

SPL specified. In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for the equipment.

NOTE ISO 3740, ISO 3744, and ISO 3746 or ASME PTC 36 may be consulted for guidance.

6.1.8 Unless otherwise specified, cooling water system or systems shall be designed for the following conditions.

Water velocity over heat exchange surfaces	5 ft/s to 8 ft/s	≥1.5 m/s to 2.5 m/s
Maximum allowable working pressure, MAWP (gauge)	≥100 psig	≥7 bar
Test pressure (≥1.5 MAWP)	≥150 psig	≥1050 kPa (10.5 bar)
Maximum pressure drop	15 psi	100 kPa (1 bar)
Maximum inlet temperature	90 °F	30 °C
Maximum outlet temperature	120 °F	50 °C
Maximum temperature rise	30 °F	20 K
Minimum temperature rise	20 °F	10 K
Water side fouling factor	0.002 h-ft^2-°F/Btu	0.35 m^{2}K/kW
Corrosion allowance for carbon steel shells	$^1/_8$ in.	3 mm

The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. If such a conflict exists the purchaser shall approve the final selection.

NOTE For water cooled bearing housings, maintaining the inlet water temperature above ambient air temp will prevent condensation of water in the bearing housing.

Provision shall be made for complete venting and draining of the system or systems.

6.1.9 The equipment's maximum continuous speed shall be not less than 105 % of the rated speed for variable speed machines [including variable-frequency drive (VFD) controlled electric motors] and shall be equal to the synchronous speed for constant speed motor drives.

6.1.10 The equipment's trip speed shall not be less than the values in Table 1.

Table 1—Driver Trip Speeds

Driver Type	Trip Speed (% of Maximum Continuous Speed)
Steam Turbine	
NEMA Class A [a]	115 %
NEMA Class B, C, D [a]	110 %
Variable-speed Motor	110 %
Constant-speed Motor	100 %

[a] Indicates governor class as specified in NEMA SM 23.

6.1.11 The arrangement of the equipment, including ducting and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance. See Annex C for typical arrangements.

• 6.1.12 Electrical Classification

6.1.12.1 Locations for installed equipment can be classified as hazardous electrical areas or they can be unclassified. An unclassified area is considered nonhazardous; therefore, motors, electrical instrumentation, equipment, components, and electrical installations for unclassified areas are not governed by hazardous area electrical codes.

• **6.1.12.2** If an installation location is classified as hazardous, motors, electrical instrumentation, equipment, components, and electrical installations shall be suitable for the hazardous electrical area classification designation as specified.

• **6.1.12.3** All applicable electrical codes shall be specified. Local electrical codes that apply shall be provided by the purchaser upon request.

NOTE 1 Electrical codes vary by installation location. Refer to Table 2 for a tabulation of common hazardous area electrical codes in use.

Table 2—Common Hazardous Area Electrical Codes

Standards Organization [a]	Codes	Where Used	Hazardous Electrical Area Classification Designation
IEC CENELEC	IEC 60079 EN 60079	EU countries and worldwide, except U.S.	Zone, Gas Group, Temperature Class
EU	ATEX Directive 94/9/EC	Required, in addition to IEC, in EU countries only. May be requested in other countries.	Equipment Group, Category
NEC ®	NFPA 70, Sections 500–502, 504	United States	Class, Division, Group, Temperature Class
NEC ®	NFPA 70, Section 505	United States	Class I, Zone, Gas Group, Temperature Class
CEC ®	CSA C22.1-06, Section 18	Canada	*Primary:* Adoption of IEC—Zone, Gas Group, Temperature Class *In Appendix:* Class, Division, Group, Temperature Class

[a] IEC: International Electrotechnical Commission; CENELEC: European Committee for Electrotechnical Standardization; ATEX: Atmospheres Explosibles,*Equipment intended for use in potentially explosive atmospheres*; EU: European Union; *NEC* ®: *National Electrical Code* ®, published by National Fire Protection Association (NFPA); *CEC* ®: *Canadian Electrical Code* ®, published by Canadian Standards Association (CSA).

NOTE 2 The ATEX directive, 94/9/EC, became effective on June 30, 2003 and applies to all equipment (mechanical and electrical) that is intended for use in a potentially explosive atmosphere, in the European Economic Area. While not a specific electrical code, it is listed in the table because most electrical products cannot be put into use in a hazardous area in the European Economic Area without ATEX certification. Also, mechanical products, which are used in the EU in a hazardous area, are required to conform to the ATEX directive. The ATEX directive defines categories, which determine the approach used to obtain ATEX certification. Electrical and mechanical equipment are required to meet the essential health and safety requirements set forth in the ATEX directive.

6.1.13 Oil reservoirs and housings that enclose moving lubricated parts such as bearings, shaft seals, highly polished parts, instruments, and control elements shall be designed to minimize contamination by moisture, dust, and other foreign matter during periods of operation and idleness.

6.1.14 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly.

NOTE This can be accomplished by the use of shouldering, cylindrical dowels, or keys.

6.1.15 The equipment (machine, driver, and ancillary equipment) shall perform on the test stand(s) and on their permanent foundation within the specified acceptance criteria. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

• **6.1.16** Many factors can adversely affect site performance. These factors include such items as duct loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's duct and foundation drawings. If specified, the vendor's representative shall witness:

a) a check of the duct alignment performed by unfastening the major flanged connections of the equipment,

b) the initial shaft alignment check at ambient conditions,

c) shaft alignment at operating temperature (i.e. hot alignment check).

• **6.1.17** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions.

• **6.1.18** The equipment, including all auxiliaries, shall be suitable for operation, using the utility stream conditions specified.

• **6.1.19** Spare and replacement parts for the machine and all furnished auxiliaries shall meet all the criteria of this standard.

6.1.20 Bolting and Threads

• **6.1.20.1** The threading shall conform to ASME B1.1 or ISO 261, as specified.

NOTE 1 ASME B1.1 covers general inch series screw threads, and ISO 261 covers general metric screw threads.

NOTE 2 For the purposes of this provision, ASME B1.13M is equivalent to ISO 261.

NOTE 3 Glossary of terms for screw threads can be found in ASME B18.12:2001.

NOTE 4 J profile threads are covered in 6.1.20.2.

6.1.20.1.1 When ASME B1.1 threads have been specified, the thread series shall be variable pitch series UNC or UNRC, or constant pitch series 4, 6, or 8 UN or UNR. Diameters shall be selected from Table 2, Column 1 of ASME B1.1. The threads shall be Class 2 for bolting, studs, and nuts. For other threads and nuts they shall be Class 2 or Class 3.

In order to prevent galling, when ASME B1.1, Class 3 external threads are used, the tolerance for maximum material conditions shall be modified to prevent zero clearance.

NOTE 1 ASME B1.1, Class 3 tolerance for the OD of the external thread and the ID of the internal thread results in zero clearances. This has resulted in galling and inability to disengage the mating components.

NOTE 2 Internal threads do not have any allowance, and therefore even if a Class 2 nut is used with a Class 3 external thread, metal-to-metal at maximum material conditions can develop.

6.1.20.1.2 When ISO 261 has been specified, the thread series shall be coarse or 3, 4, 6, or 8 pitch. Diameters shall be selected from Table 2, Column 1 of ISO 261. The threads shall be Class 6g for bolting and studs and Class 6H for nuts. For other threads they shall be Class 6g or 4h for external threads and Class 6H or 5H for internal threads.

In order to prevent galling, when ISO Class h/H position is specified for mating components, the tolerance for maximum material conditions shall be modified to prevent zero clearance.

NOTE 1 ISO position h/H clearance for the OD of the external thread and the ID of the internal thread can result in 0 clearance between the mating components. This has resulted in galling and inability to disengage the mating components.

NOTE 2 Internal threads position G in the ISO system have an allowance, and therefore a nut using position G can be used with a position h external thread and not develop metal-to-metal contact.

• **6.1.20.2** When J profile threads are used, they shall comply with ASME B1.15 or ISO 5855-1 as specified.

NOTE 1 ASME B1.15 covers J profile screw threads, and ISO 5855-1 covers general metric J profile screw threads,

NOTE 2 For the purposes of this provision, ASME B1.21M:1978 is equivalent to ISO 5855-1 and ISO 5855-2.

6.1.20.2.1 When ISO 5855-1 has been specified, the thread series shall be coarse or 3 pitch as required by Table 2 of ASME B1.21M. Diameters shall be selected from Table 2, Column 1 of ASME B1.21M. The threads shall be Class 4h6h for bolting studs and 4H5H for nuts. Threads other than those for fasteners shall be Class 6g or 4h for external threads and Class 6H or 5H for internal threads. In order to prevent galling, when ISO Class h/H position is specified for mating components, the tolerance for maximum material conditions shall be modified to prevent zero clearance.

NOTE 1 ISO position h/H clearance for the OD of the external thread and the ID of the internal thread can result in 0 clearances. This has resulted in galling and inability to disengage the mating components.

NOTE 2 Internal threads position G in the ISO system have an allowance, and therefore a nut using position G can be used with a position h external thread and not develop metal-to-metal contact.

6.1.20.2.2 When ASME B1.15 (inch series) threads have been specified, the thread series shall be variable pitch series UNJC or constant pitch series 8-UNJ. The threads shall be Class 2 or Class 3. Diameters shall be selected from Table 2, Column 1 of ASME B1.15.

In order to prevent galling, when ASME B1.15, Class 3 external threads are used, the tolerance for maximum material conditions shall be modified to prevent zero clearance.

NOTE 1 ASME B1.15, Class 3 tolerance for the OD of the external thread and the ID of the internal thread results in zero clearances. This has resulted in galling and inability to disengage the mating components.

NOTE 2 Internal threads do not have any allowance, and therefore even if a Class 2 nut is used with a Class 3 external thread, metal-to-metal at maximum material conditions can develop.

6.1.20.2.3 When J profile threads are used, external threads shall be formed by rolling.

6.1.20.3 Gaging

6.1.20.3.1 Inspection or gaging requirements of threads shall be identified in accordance with ASME B1.1, Section 6—Screw Thread Designation.

6.1.20.3.2 All threaded products shall be visually inspected for gross defects. This visual inspection shall be made without magnification and is intended to detect such gross defects as missing or incomplete threads, defective thread profile, torn or ruptured surfaces and cracks, etc.

6.1.20.4 Adequate clearance shall be provided at all bolting locations to permit the use of socket or box wrenches.

6.1.20.5 Internal socket-type, slotted-nut, or spanner-type bolting shall not be used unless approved by the purchaser.

NOTE For limited space locations, integrally flanged fasteners may be required.

6.1.20.6 Manufacturers marking shall be located on all fasteners 1/4 in. (6 mm) and larger (excluding washers and headless set screws). For studs, the marking shall be on the nut end of the exposed stud end.

NOTE A set screw is a headless screw with an internal hex opening on one end.

• **6.1.21** Fluids that are flammable, hazardous, or toxic shall be identified by the purchaser.

6.1.22 Fan speed shall not exceed 1800 rpm for any operating condition.

6.1.23 Fan arrangement and bearing support shall be in accordance with AMCA 99-86 and AMCA 99-2404-78, arrangement 3 or 7, with fan impeller located between bearings, the bearings mounted independently of fan housing on rigid pedestals and soleplates, and the bearings protected from the air or gas stream when any of the following conditions exist:

a) the driver rated power is 150 BHP (120 kW) or greater,

b) the maximum specified operating temperature is greater than 450 °F (233 °C),

c) when operating in a corrosive or erosive service,

d) the operating service is subject to fouling deposits that could cause rotor unbalance.

6.1.24 When drivers are rated less than 40 BHP (30 kW), AMCA arrangements 1, 8, and 9 may be specified on the datasheet.

6.1.25 Fan performance shall be based on the static pressure rise across the fan inlet and outlet flanges. In specifying required operating conditions on the datasheet, the purchaser is responsible for accounting for inlet velocity pressure. The fan vendor is responsible for including the pressure losses attributed to all items within his/her scope to obtain the required static pressure rise. Refer to Figure 2 and AMCA 801-01, Section 3.

The performance curves in Figure 3 reflect general characteristics of various types of fans commonly used. They are not intended to provide complete selection criteria for application purposes since other pertinent parameters are not defined.

6.1.26 The fan shall be capable of stable operation at all operating conditions specified by the purchaser.

NOTE This may require the use of dampers or variable speed control.

6.1.27 Unless otherwise specified, fan curves shall have continuously rising pressure characteristic (pressure versus flow plot) from the rated capacity to 70 % or less of rated flow.

Performance curves, corrected for the specified gas at the specified conditions, shall be based on performance tests in accordance with AMCA 210, including, where applicable, evase and inlet box(es).

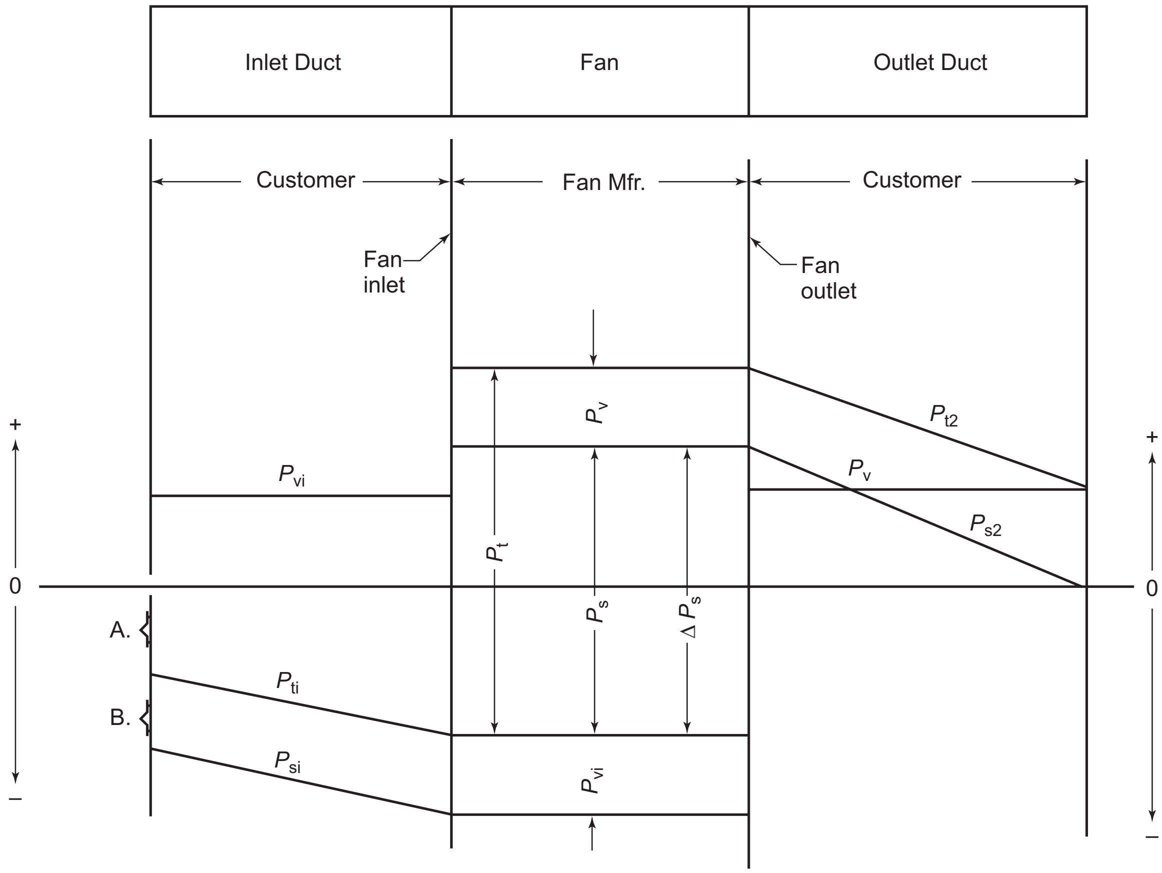
6.1.28 Fans shall be designed such that the first bending critical speed is a minimum of 20 % above the maximum continuous speed.

6.1.29 Induced draft fans shall be mechanically designed for operation at 100 °F (55 °C) above maximum specified inlet gas temperature.

6.1.30 Fan, components, and accessories shall be designed to withstand all loads and stresses during rapid load changes, such as across-the-line starting of motor drivers, failure of damper operator, and sudden opening of dampers.

6.1.31 On forced draft fans, the provision of inlet equipment and arrangements, including silencer(s) and transition piece(s), shall be coordinated between the purchaser and the fan vendor. Unless otherwise specified, air intake(s) shall be at least 15 ft (4.5 m) above the grade.

NOTE The purchaser should evaluate air intake elevation requirements, considering the possibility of dust entering the system and causing surface fouling, the area noise limitation requirement and corresponding need for a silencer, possibility of a combustible vapor entering the fan, and possible horsepower penalties of inlet stack and silencer configurations.



A. Entrance Loss B. Acceleration Energy

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

2. Velocity Pressure is that portion of the air pressure which exists by virtue of the rate of motion only. It is always positive.

3. Total Pressure is 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.

4. Fan Total Pressure (P_t) is the difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

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

5. Fan Velocity Pressure (P_v) is the pressure corresponding to the average velocity at the specified fan outlet area.

$$P_v = P_{v2}$$

6. Fan Static Pressure (P_s) is 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.

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

7. Fan Static Pressure Rise (ΔP_s) is the static pressure at the fan outlet minus the static pressure at the fan inlet.

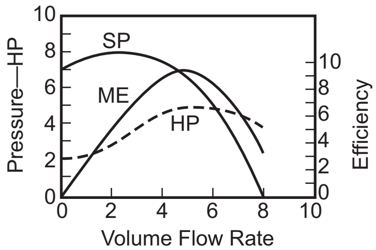
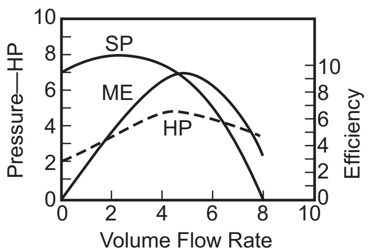
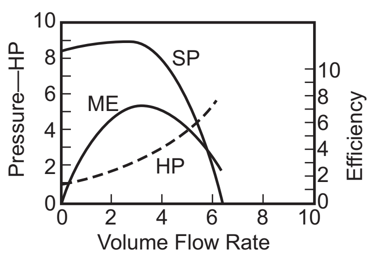
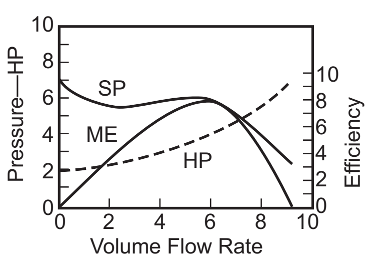
$$\Delta P_s = P_{s2} - P_{s1}$$

The difference between fan static pressure and static pressure rise is the inlet velocity pressure.

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

Adapted from AMCA Publication 801-01 (R2008), *Industrial Process/Power Generation Fans: Specification Guidelines.*

Figure 2—Fan Pressure Rise Terms

<table>
<tr><td></td><td>Highest efficiencies occur 50 % to 65 % of wide open volume. This is also the area of good pressure characteristics; the horsepower curve reaches a maximum near the peak efficiency area and becomes lower toward free delivery, a self-limiting power characteristic as shown.</td><td>General heating, ventilating, and air-conditioning systems. Used in large sizes for clean air industrial applications where power savings are significant.</td></tr>
<tr><td></td><td>Operating characteristics of this fan are similar to the airfoil fan mentioned above. Peak efficiency for this fan is slightly lower than the airfoil fan. Normally unstable left of peak pressure.</td><td>Same heating, ventilating, and air-conditioning applications as the airfoil fan. Also used in some industrial applications where the airfoil blade is not acceptable because of corrosive and/or erosion environment.</td></tr>
<tr><td></td><td>Higher pressure characteristics than the above mentioned fans. Power rises continually to free delivery.</td><td>Used primarily for material-handling applications in industrial plants. Wheel can be of rugged construction and is simple to repair in the field. Wheel is sometimes coated with special material. This design is also used for high-pressure industrial requirements. Not commonly found in HVAC applications.</td></tr>
<tr><td></td><td>Pressure curve is less steep than that of backward-curved bladed fans. There is a dip in the pressure curve left of the peak pressure point and highest efficiency occurs to the right of peak pressure, 40 % to 50 % of wide open volume. Fan should be rated to the right of peak pressure. Power curve rises continually toward free delivery, and this must be taken into account when motor is selected.</td><td>Used primarily in low-pressure heating, ventilating, and air-conditioning applications such as domestic furnaces, central station units, and packaged air-conditioning equipment from room air-conditioning units to rooftop units.</td></tr>
</table>

Adapted from AMCA 201-02 (R2011), *Fans and Systems*

Figure 3—Fan Characteristic Curves

6.1.32 Fan inlet equipment for atmospheric air intake applications shall include intake cap or hood, trash screen, ducting and support, inlet damper or guide vanes, inlet boxes, and silencer, as required. All components shipped separately shall be flanged for assembly. The inlet equipment assembly shall be designed for the wind load shown on the fan datasheet. The minimum thickness for the above components shall be $^{3}/_{16}$ in. (4.75 mm).

• **6.1.33** If specified, fans shall be designed to allow installation of fan blade cleaning systems. The fan vendor shall provide drawings showing the suggested mounting of this system. As a minimum these drawings shall include:

1) connection size, location, and material;

2) recommended element make, model, size, and material;

3) recommended cleaning medium, with required pressure and temperature;

4) recommended frequency and duration of cleaning;

5) any other operating limitations.

Elements of the blade cleaning system inside the fan housing shall be supplied by the fan vendor and made of corrosion resistant material. The internal system shall be supported to prevent vibration damage. The purchaser will specify available cleaning media pressure and temperature.

6.2 Fan Housing

6.2.1 The fan scroll and housing shall be continuously welded plate construction. For corrosive, erosive, or hazardous gas service, the pressure containing joints of the fan housing shall be continuously welded inside and out. For arrangement 3 fans (see Annex C), the housing and inlet box(es) shall be split with a bolted, flanged, and gasketed connection to allow for removal of the assembled rotor without disturbing the duct connections. Other arrangements shall be similarly constructed when rotor diameters exceed 43 in. (1100 mm). Minimum housing plate thickness shall be $^{3}/_{16}$ in. (5 mm) for forced draft fans and $^{1}/_{4}$ in. (6 mm) for induced draft fans. The housing shall be free of fan induced structural resonance(s) and limit vibration and noise. Stiffeners shall be provided when required. Stiffeners shall be noncontinuously welded and caulked. The inlet cone shall be split, separately removable, or removable as an assembly with the rotor.

6.2.2 Bolted and gasketed access doors, minimum 24 in. × 24 in. (600 mm × 600 mm) shall be provided in the scroll and inlet box(es) to access the fan internals for inspection, cleaning, rotor balancing, and any internal bolting necessary for rotor removal. If fan size and construction will not permit this size access doors, the largest practical access openings shall be provided in the scroll and inlet box(es).

6.2.3 Adequate flanged sections shall be provided in the fan housing and inlet box(es) so that the rotor can be removed and installed without requiring personnel to enter the inlet box(es) or fan housing.

NOTE Access to enclosed spaces should be limited because of the safety considerations of personnel entering a confined area. An exception to this requirement may be acceptable for specific application(s) provided confined space safety considerations are properly addressed. Appropriate procedures that meet the requirements of OSHA 29 *CFR* 1910.146, *Permit Required Confined Spaces* and OSHA 29 *CFR* 1910.147, *The Control of Hazardous Energy (Lockout/Tag Out)* should be observed, and measures should be taken to positively mechanically disconnect all prime movers from the fan. This can include removal of coupling elements and the application of temporary shaft clamping devices to prevent autorotation of the fan rotor.

6.2.4 If specified, induced-draft fan housings shall have side and full width scroll liner(s) of abrasion-resistant material. The material shall be retained in place as agreed by the vendor and purchaser. As an option double thick scroll and side-wall of "standard" materials may be specified.

• **6.2.5** If specified, or when deemed necessary by the fan vendor, the fan housing shall be supported close to the horizontal centerline to minimize changes in housing/rotor relative position and maintain shaft to housing seal clearances and alignment within manufacturer's limits. It is the fan vendor's responsibility to ensure that all clearances are adequately controlled over the range of temperatures for which the fan is specified to operate.

NOTE A fan housing is normally supported from feet mounted at the lowest point. Because the fan rotor is usually separately supported, changes in relative position between rotor and housing will result from thermal expansion.

6.2.6 All mounting surfaces shall be in the same horizontal plane within 0.0625 in. (1 mm). Hold-down bolt holes shall be drilled perpendicular to the mounting surface(s), machined or spot faced to a diameter 3 times that of the bolt. To allow for equipment alignment the hole shall be $^{1}/_{2}$ in. (12 mm) larger in diameter than the hold-down bolt.

6.3 Fan Housing Connections

6.3.1 Inlet and discharge connections shall be flanged and bolted. Facings, gaskets, and bolting of all connections shall be adequate to prevent leakage when using gaskets of at least $^1/_8$ in. (3 mm) thickness. Unless otherwise specified, gaskets and bolting for the purchaser's inlet and discharge connection shall be specified by the vendor and will be provided by the purchaser.

• **6.3.1.1** When inlet and discharge connections of different size or shape than those covered by ASME are supplied (such as for ducting), the vendor shall supply equipment flange details to the purchaser for the purpose of manufacturing mating parts. If specified, the mating parts shall be furnished by the vendor.

6.3.1.2 Flanged inlets are not mandatory for open inlet fans, but may be provided at the manufacturer's discretion. Alternate acceptable inlet types are bell mouth inlets, coned inlets, or straight inlets. Safety guards to prevent ingress of foreign objects and/or prevent bodily contact with moving parts shall be provided on an open inlet as defined in 7.7.

6.3.2 Auxiliary Connections

6.3.2.1 Fan housing openings for pipe connections shall be NPS $^3/_4$ (DN 20) or larger and shall be in accordance with ISO-6708:1995. Sizes NPS 1 $^1/_4$, 2 $^1/_2$, 3 $^1/_2$, 5, 7, and 9 (DN 32, DN 65, DN 90, DN 125, DN 175, and DN 225) shall not be used.

6.3.2.2 All connections shall be flanged or machined and studded, except where threaded connections are permitted by 6.3.2.5. All connections shall be suitable for the MAWP of the fan casing. Flanged connections may be integral with the casing or, for casings of weldable material, may be formed by a socket-welded or butt-welded pipe nipple or transition piece and shall terminate with a welding-neck or socket-weld flange.

6.3.2.3 Connections welded to the casing shall meet the material requirements of the casing, including impact values rather than the requirements of the connected piping (see 6.10.3).

6.3.2.4 Butt-welded connections, size NPS 1 $^1/_2$ (DN 40) and smaller, shall be reinforced by using forged welding inserts or gussets.

6.3.2.5 For connections other than main process connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding NPS 1 (DN 25) may be used with purchaser approval as follows:

a) on nonweldable materials, such as cast iron;

b) where essential for maintenance (disassembly and assembly).

6.3.2.6 Pipe nipples screwed or welded to the casing should not be more than 6 in. (150 mm) long and shall be a minimum of Schedule 160 seamless for sizes NPS 1 (DN 25) and smaller and a minimum of Schedule 80 for NPS 1 $^1/_2$ (DN 40).

6.3.2.7 The nipple and flange materials shall meet the requirements of 6.3.2.3.

6.3.2.8 Threaded openings for tapered pipe threads shall conform to ASME B1.20.1 or ISO 7-1 as specified. If ISO 7-1 has been specified, tapered or straight internal threads shall also be specified. Bosses for pipe threads shall conform to ASME B16.5.

6.3.2.9 Threaded connections shall not be seal welded.

6.3.2.10 Threaded openings not required to be connected to piping shall be plugged with solid, round-head steel plugs furnished in accordance with ASME B16.11. As a minimum, these plugs shall meet the material requirements of the casing. Plugs that may later require removal shall be of corrosion-resistant material. Plastic plugs are not permitted.

6.3.2.11 A process compatible thread lubricant of proper temperature specification shall be used on all threaded connections. Thread tape shall not be used.

6.3.2.12 Pipe Flanges

• **6.3.2.12.1** Pipe flanges shall conform to ISO 7005-1, Series 1, including Annex D and Annex E; ISO 7005-2, Series 1; ASME B16.1; ASME B16.5; ASME B16.42; or ASME B16.47 (Series B) as specified, except as specified in 6.3.2.12.2 through 6.3.2.12.6.

NOTE 1 ISO 7005-1 (steel flanges) PN 20, 50, 110, 150, 260, and 420 are designed to be interchangeable with ASME B16.5 and MSS SP-44 flanges—ISO 7005-1 flanges are not identical to ASME B16.5 and MSS SP-44 flanges but are deemed to comply with the dimensions specified in ASME B16.5 and MSS SP-44.

NOTE 2 ISO PN 2.5 and 6 do not have a corresponding ASME class, and ASME Classes 75, 400, and 800 do not have corresponding ISO PN designation. The use of these PN and class flange ratings is therefore not recommended.

6.3.2.12.2 When ISO 7005-1 has been specified, materials shall be in accordance with ISO 7005-1 Annex D-1 (DIN) or Annex D-2 (ASTM) as specified. The pressure temperature ratings in Annex E shall correspond to the materials specified.

NOTE ISO 7005-1, Annex E, Table 1-4 covers D-1 materials and Table 5-21 covers D-2 materials.

• **6.3.2.12.3** If specified, ASME B16.47, Series A flanges shall be provided.

6.3.2.12.4 Flat face flanges with full raised face thickness are acceptable on casings of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO or ASME are acceptable. Nonstandard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of nonstandard length, this requirement shall be identified on the arrangement drawing.

6.3.2.12.5 Flanges shall be full faced or spot faced on the back and shall be designed for through bolting.

6.3.2.12.6 For all steel flanges, imperfections in the flange facing finish shall not exceed that permitted in ASME B16.5 or ASME B16.47 as applicable.

• **6.3.2.12.7** Machined and studded connections shall conform to the facing and drilling requirements of ISO 7005-1, ISO 7005-2, ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47 as specified. Studs and nuts shall be provided and installed. The first 1.5 threads at both ends of each stud shall be removed.

6.3.2.12.8 Machined and studded connections and flanges not in accordance with ISO 7005-1, ISO 7005-2, or ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs, and nuts for these nonstandard connections.

6.3.2.12.9 To minimize nozzle loading, and facilitate installation of piping, machine flanges shall be parallel to the plane shown of the flange as shown on the general arrangement drawing to within 0.5°. Studs or bolt holes shall straddle centerlines parallel to the main axes of the equipment.

6.3.2.12.10 All of the purchaser's connections shall be accessible for disassembly without requiring the machine, or any major part of the machine, to be moved.

6.3.2.12.11 Accessible flanged drain connections, NPS 2 (DN 50) minimum size, shall be provided at the low points of the housing and inlet boxes.

6.3.2.12.12 The concentricity of the bolt circle and the bore of all circular standard flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

6.3.2.12.13 For socket-welded construction, there shall be a $^{1}/_{16}$ in. (1.5 mm) gap between the pipe end and bottom of the socket before welding.

6.3.2.12.14 Slip-on flanges are permitted only with the purchaser's specific approval.

6.4 External Forces and Moments

6.4.1 It is the purchaser's responsibility to specify the external loads to be imposed on the fan housing from the ancillary equipment (ducting, sound trunks, silencers, filters, etc.) if this equipment is not supplied by the fan vendor. The vendor shall design the housing and supports to accept the specified loads such that:

a) distortion resulting from imposed loads does not affect performance, and

b) no internal rubs result.

6.5 Rotating Elements

6.5.1 Materials selection shall be by joint agreement between the purchaser and vendor. The vendor shall fully detail materials, thickness, and construction details for each rotor assembly.

6.5.2 Fan impellers shall be designed for the highest efficiency consistent with the application. Blade design shall be mutually agreed upon between the purchaser and vendor.

NOTE 1 Forced draft fan impellers may be provided with backward inclined or backward curved airfoil type. Induced-draft fans impellers may be radial, radial tipped, backward inclined, or backward curved airfoil type, with consideration of operation in possibly dirty gas environment.

NOTE 2 Design configurations listed below are available options.

a) Hollow-shaped airfoil construction of 0.10 in. (2.5 mm) minimum thickness skin material, designed and constructed to prevent the internal accumulation of condensable foulants or corrosion products. The purchaser should exercise care in the application of this design in corrosive and/or erosive environments such as found in some induced draft services.

b) Solid blades with airfoil shape.

c) Single thickness, $^{1}/_{4}$ in. (6 mm) minimum, non-airfoil shape.

6.5.3 Welded construction of the fan impeller is required. Shrouds, back plates, and center plates shall normally be of one-piece construction but may be fabricated if the sections are joined by full strength/penetration butt welds. Corrosiveness, erosiveness, and temperature (including excursions) of gas specified by the purchaser shall be considered during material selection.

• **6.5.4** If specified, corrosion-resistant shaft sleeves shall be provided. Sleeves shall extend 6 in. (150 mm) into the fan housing or to the impeller hub. Shaft sleeves shall be installed with an interference fit, and the fit and assembly shall take into account differential thermal expansion at the highest operating temperature. After assembly of the shaft, mechanical run out on the shaft sleeve shall not exceed 0.002 in. (50 μm) total indicated runout (TIR) in the seal area.

6.5.5 Impellers shall have solid hubs, be keyed to the shaft, and be secured with an interference fit. Unkeyed fits with appropriate interference are permissible with purchaser's approval. The fit shall have a minimum interference of 0.0005 in. per in. (0.0005 mm per mm) of bore diameter; however, the actual interference fit shall be shown on the datasheet and outline drawing. The impeller hub to shaft fit design shall preclude axial movement of the hub along the shaft caused by gross changes in temperature. The hub bore and shaft outside diameter shall be machined to a finish of 32 μin. (0.8 μm) arithmetic average roughness (Ra) or better in the interference fit contact area. Cast or ductile iron hubs or hollow hubs are not acceptable except in services below 300 °F (150 °C) or at a fan tip speed of less than 20,000 ft/min. (100 m/s). When the impeller is to be bolted to the hub, the manufacturer will, by design, preclude relative movement between the impeller and hub.

• **6.5.6** The purchaser will specify on the datasheet the rate of temperature change—heating and cooling—for the process operating conditions. The vendor shall assure that an adequate interference fit (hub to shaft) is maintained considering purchaser's defined operating conditions, including transients.

6.5.7 Each rotor shall be clearly marked with a unique identification number. This number shall be on the nondrive end of the shaft or in another accessible area that is not prone to maintenance damage.

6.5.8 Shafting including shaft to coupling juncture shall be capable of transmitting torque at least equal to the maximum transient torque produced by the driver during acceleration including service factor, if any.

6.5.9 Shafts shall be machined from one-piece heat treated steel. Shafts with finished diameters 8 in. (200 mm) and larger shall be forged. Shafts with finished diameters less than 8 in. (200 mm) may be hot-rolled bar stock purchased to the same quality and heat treatment criteria as shaft forgings. Shafts made from forgings or from bar stock shall be stress relieved after rough machining and before final machining. Cold rolled steel, turned, ground, and polished, may be used for shafts not exceeding 4 in. (100 mm) finished diameter. Shaft diameter for arrangements 3 and 7 shall be stepped on both sides of impeller fit area to facilitate impeller removal. Fillets shall be provided at all changes in shaft diameters. Welding on the shaft is not permitted.

6.5.10 All shaft keyways shall have fillet radii conforming to ASME B17.1.

6.5.11 Shaft shoulders against which rolling element bearings seat shall have filets conforming to ISO 582. When inch series tapered roller bearings are used, the filets shall be in accordance with ABMA 19.2.

NOTE For the purpose of this provision ABMA 20 and ABMA 19.1 are equivalent to ISO 582.

6.6 Shaft Sealing of Fans

6.6.1 Shaft seals, including labyrinth, floating bushing (e.g. carbon ring), or close clearance annulus types shall be provided to minimize leakage from or into fans over the range of specified operating conditions and during periods of idleness. Seals shall be designed to operate for process conditions that may vary during start-up and shutdown or any special operation specified by the purchaser.

6.6.2 Fans with negative pressure at the shaft seals, except forced draft fans in air service and induced draft fans exhausting to the atmosphere, shall be provided with seals suitable for pressurization. System details shall be mutually agreed upon by the purchaser and the vendor.

6.6.3 When the seal is specified to be in toxic, high-pressure, or flammable service, provision for a centralized buffer gas injection and/or eductor system shall be supplied to minimize leakage. System details shall be mutually agreed upon by the purchaser and the vendor.

6.6.4 Shaft sealing elements shall be replaceable without disturbing the shaft and bearings or dismantling ductwork or the fan casing.

6.6.5 Shaft seal clearances and materials shall be based on the specified operating temperature. Temperature excursions shall also be considered in the design.

6.6.6 Requirements for Special Purpose Fans

• If specified, fan shall be equipped with mechanical seals or dry gas seals.

6.7 Dynamics

6.7.1 General

6.7.1.1 When the frequency of a periodic forcing phenomenon (excitation) applied to a rotor-bearing support system coincides with a natural frequency of that system, the system will be in a state of resonance. A rotor-bearing support system in resonance may have the magnitude of its normal vibration amplified. The magnitude of amplification and, in the case of critical speeds, the rate of change of the phase angle with respect to speed are related to the amount of damping in the system.

NOTE The mode shapes are commonly referred to as the first-rigid (translatory or bouncing) mode, the second (conical or rocking) mode, and the (first, second, third...*n*th) bending mode.

6.7.1.2 When the rotor amplification factor (see Figure 4), as measured at the shaft radial vibration probes, is greater than or equal to 2.5, the corresponding frequency is called a critical speed and the corresponding shaft rotational frequency is also called a critical speed. For the purpose of this standard, a critically damped system is one in which the amplification factor is less than 2.5.

NOTE This speed is defined in AMCA 801-01 under the heading "Design Criteria" as "design resonant speed."

6.7.1.3 In the design of rotor-bearing systems, consideration shall be given to all potential sources of periodic forcing phenomena (excitation), which shall include but are not limited to the following sources:

a) unbalance in the rotor system,

b) oil film instabilities (whirl),

c) blade passing frequencies,

d) gear tooth meshing and side bands,

e) coupling misalignment,

f) loose rotor system components,

g) ball and race frequencies of rolling element bearings,

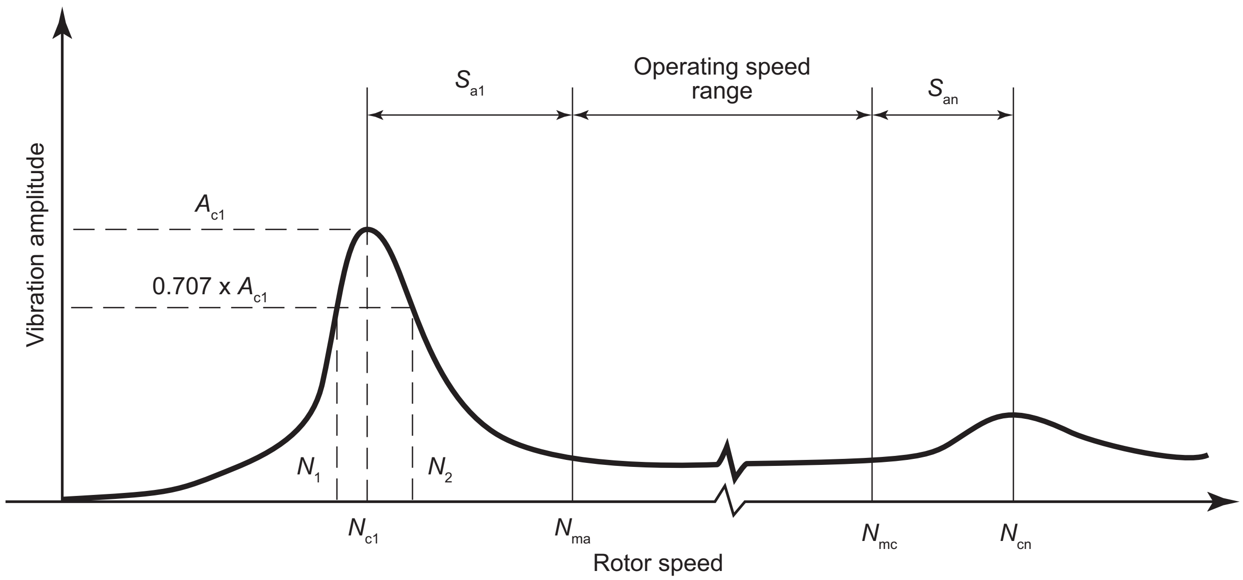
h) VFD excitation frequencies.

NOTE The frequency of a potential source of excitation can be less than, equal to, or greater than the rotational speed of the rotor.

6.7.1.4 Resonances of structural support systems may adversely affect the rotor vibration amplitude. Therefore, resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified operating speed range or the specified separation margins (see 6.7.2.1 and Annex D) unless the resonances are critically damped. The effective stiffness of the structural support shall be considered in the analysis of the dynamics of the rotor-bearing support system.

6.7.1.5 The vendor who is specified to have unit responsibility for the complete drivetrain shall communicate the existence of any undesirable running speeds in the range from zero to trip speed. This shall be illustrated by the use of Campbell (forced frequency) diagrams for individual machines and/or when specified for the complete train. These diagrams shall be submitted to the purchaser for his/her review and included in the instruction manual (see D.5).

NOTE Examples of undesirable speeds are those caused by the rotor lateral criticals of concern, system torsionals, and impeller resonant frequencies.



N_{c1} = rotor first critical speed
N_{cn} = n^{th} critical speed
N_{ma} = minimum allowable speed
N_{mc} = maximum continuous speed

A_{c1} = amplitude at N_{c1}
N_1 = initial (lesser) speed at $0.707 \times A_{c1}$
N_2 = final (greater) speed at $0.707 \times A_{c1}$
AF_1 = amplification factor of the first critical speed
= $N_{c1} / (N_2 - N_1)$

S_{a1} = actual separation between N_{c1} and the operating speed range
S_{an} = actual separation between N_{cn} and the operating speed range
SM_{a1} = actual separation margin of first critical speed (%)
= $100 \times S_{a1} / N_{ma}$
SM_{an} = actual separation margin of n^{th} critical speed (%)
= $100 \times S_{an} / N_{mc}$

NOTE The shape of the curve is for illustration only and does not necessarily represent any actual rotor response plot.

Figure 4—Rotor Response Plot

6.7.2 Lateral Analysis

6.7.2.1 Unless otherwise specified, the vendor's standard lateral critical speed values that have been analytically derived and proven by testing of identical fans, similar fans, or fans where the first bending critical speed is a minimum of 20 % above the maximum continuous speed are acceptable.

An identical fan is defined as one with the same size frame, aerodynamic design, rpm, size and type of shaft seal, size and type of bearings, and coupling mass and overhang.

Similarity between fans shall be established by agreement between the purchaser and vendor, considering the factors listed above.

• **6.7.2.2** If specified, a lateral analysis shall be carried out and the results assessed in accordance with Annex D.

6.7.3 Torsional Analysis

• **6.7.3.1** A torsional analysis shall be performed for any of the following:

a) electric motor or steam turbine driven fans with gears over 200 hp (150 kW),

b) units comprising three or more coupled machines (excluding any gears),

c) all VFD driven units,

d) internal combustion engine rated 325 hp (250 kW) or higher,

e) synchronous motor rated 700 hp (500 kW) or higher.

The vendor having unit responsibility shall ensure that the analysis is carried out and shall be responsible for directing any modifications necessary to meet the requirements of 6.7.3.2 through 6.7.3.7.

The analysis shall be for the train as a whole unless the train includes a device that has weak dynamic coupling, for example, a hydraulic coupling or torque converter.

The purchaser shall specify if a torsional analysis is required for motor driven units without gears.

6.7.3.2 Excitation of torsional natural frequencies may come from many sources that may or may not be a function of running speed and should be considered in the analysis. These sources shall include but are not limited to the following:

a) gear characteristics such as unbalance, pitch line runout, and cumulative pitch error;

b) cyclic process impulses;

c) torsional transients such as start-up of synchronous electric motors;

d) torsional excitation resulting from electric motors and reciprocating engines;

e) control loop resonances from hydraulic, electronic governors, and VFDs;

f) 1 and 2 times line frequency;

g) running speed or speeds;

h) harmonic frequencies from VFDs.

6.7.3.3 Excitation at the following frequencies shall be evaluated ("rpm" refers to rotor speed; "n" is an integer determined by the driver manufacturer):

a) train with gear(s): 1 and 2 times rpm.

b) synchronous motor: $n \times$ slip frequency or rpm (n = number of poles), 1 and 2 times line frequency.

c) VFD: 1 and 2 times line frequency and harmonic excitations due to the VFD as determined by the manufacturer of the VFD.

The excitation frequencies for motor drives, Items b) and c), include transient and steady state conditions.

6.7.3.4 The torsional natural frequencies of the complete train shall be at least 10 % above or 10 % below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

6.7.3.5 Torsional natural frequencies at 2 or more times running speed shall be shown to have no adverse effect.

6.7.3.6 When torsional resonances are calculated to fall within the margin specified in 6.7.3.4 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping shall be clearly stated. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

6.7.3.7 In addition to the torsional analyses required in 6.7.3.1 through 6.7.3.6, the vendor shall perform a transient torsional vibration analysis for synchronous motor driven units. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

6.7.3.8 In addition to the parameters used to perform the torsional analysis specified in 6.7.3.1, the following shall be included:

a) motor average torque, as well as pulsating torque (direct and quadrature axis) vs speed or time characteristics;

b) load torque vs speed characteristics;

c) electrical system characteristics affecting the motor terminal voltage or the assumptions made concerning the terminal voltage including the method of starting, such as across the line, or some method of reduced voltage starting.

6.7.3.9 The analysis shall generate the maximum torque as well as a torque vs time history for each of the shafts in the machinery train. The maximum torques shall be used to evaluate the peak torque capability of coupling components, gearing, and interference fits of components such as coupling hubs. The torque vs time history shall be used to develop a cumulative damage fatigue analysis of shafting, keys, and coupling components.

6.7.4 Vibration and Balancing

6.7.4.1 Prior to rotor assembly, the shaft shall be inspected for mechanical runout and concentricity at impeller mounting surface and bearing journals. Runout shall not exceed the following TIR.

Shaft Diameter (At Point Measured)		**Total Indicator Reading Impeller Mounting Area/Journal**	
in.	mm	in.	mm
≤6	≤150	0.002/0.001	0.05/0.025
>6, ≤14	>150, ≤360	0.003/0.0015	0.075/.0.38
>14	>360	0.004/0.002	0.10/0.05

A runout recheck adjacent to the hub shall be made after rotor assembly and prior to balancing. Certified runout reports shall be furnished by the vendor.

6.7.4.2 Balance weights, if required, shall not exceed 1/4 in. (6 mm) in thickness or exceed the thickness of the member to which the weight is attached and shall be continuously welded onto the impeller in two or three defined balancing planes. Those balance weights required in the gas passage shall be ground to the impeller surfaces at a fillet angle not exceeding 20°.

6.7.4.3 Impellers and similar major rotating components shall be dynamically balanced to ISO 1940, Grade 2.5. The rotating element shall be multiplane dynamically balanced. When spare rotors are supplied, they shall be dynamically balanced to the same tolerance as the main rotor.

6.7.4.4 During the shop test of the assembled machine, operating at maximum continuous speed or at any other speed within the specified operating speed range, the maximum allowable unfiltered peak amplitude of vibration in any plane measured on the bearing housing shall not exceed the value given in Table 3. At the trip speed of the driver, the vibration shall not exceed 150 % of these values.

Table 3—Vibration Limits for Fans [a]

	Point of Measurement			
	Bearing Housing		**Shaft [b]**	
	All Fan Bearings		Hydrodynamic Fan Bearings (J/B)	
	mm/s (rms)	in./s (rms)	micron	mils (pk/pk)
Unfiltered	<2.8	<0.11	<50	<2
Filtered [c]	<1.8	<0.07	<40	<1.6

[a] At any flow within the specified operating envelope.

[b] Applies when optional API 670 proximity type probes are purchased and installed adjacent to hydrodynamic bearings.

[c] At discrete frequencies.

6.7.5 Additional Requirements for Special Purpose Fans

6.7.5.1 A lateral analysis shall be performed for all special purpose applications.

• **6.7.5.1.1** If specified, the effects of other equipment in the train shall be included in the damped unbalanced response analysis (i.e. a train lateral analysis shall be performed). A train lateral analysis need not be considered unless one or more rigid couplings are employed in the drivetrain.

NOTE This analysis should be considered for machinery trains with long coupling spacers [more than 36 in. (91 cm)], rigid couplings, or both.

6.7.5.1.2 In addition to the damped unbalanced response analysis requirements of Annex D, for machines equipped with rolling element bearings, the vendor shall state the bearing stiffness and damping values used for the analysis and either the basis for these values or the assumptions made in calculating the values.

6.7.5.1.3 The maximum allowable residual unbalance per plane (journal) shall be calculated as follows: a separate damped unbalanced response analysis shall be conducted for each critical speed within the speed range of 0 to 1.5 × N_{mc}. Unbalance shall analytically be placed at the locations defined in Figure D.2. For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads. For conical (asymmetric) modes, these unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing. For overhung modes, the unbalances shall be based on the overhung mass. Section D.2 shows the typical mode shapes and indicates the location and definition of U_a for each of the shapes. The magnitude of the unbalances shall be 2 times the value of U_r as calculated by Equations (1) or (2).

In SI units:

$$U_r = 6350W/N_{mc} \tag{1}$$

In USC units:

$$U_r = 4W/N_{mc} \tag{2}$$

where

$U_a = 2 \times U_r$ is the input unbalance for the rotordynamic response analysis in oz-in. (g-mm);

U_r is the maximum allowable residual unbalance in oz-in. (g-mm);

N_{mc} is the maximum continuous operating speed, rpm;

W is the journal static load in lbm (kg), or for bending modes where the maximum deflection occurs at the shaft ends, the overhung mass (i.e. the mass of the rotor outboard of the bearing) in lbm (kg) (see Figure D.2).

NOTE 1 Refer to Annex D of this standard for more detailed explanations of the lateral critical speed analysis required.

NOTE 2 ISO Grade 1.0 is approximately equivalent to $4W/N$.

NOTE 3 If the components for the equipment are relatively light in weight and/or operates at high speed, the limits given in this paragraph may not be achievable with commercial balancing machines.

• **6.7.5.1.4** For fans over 500 hp (370 kW) supplied with baseplates that provide an integral support for the drive and fan bearings, a finite element analysis or equivalent shall be performed to determine the baseplate stiffness to be used in the critical speed analysis and to determine baseplate resonant frequencies and mode shapes that could be excited by operational forces.

6.7.5.2 Vibration and Balance for Special Purpose Fans

6.7.5.2.1 On rotors with keyways, the keyway shall be filled with a fully crowned half-key. The weight of all half-keys used during final balancing of the assembled element shall be recorded on the residual unbalance worksheet (see Annex E). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

In SI units:

$$U_{max} = 6350W/N \tag{3}$$

In USC units:

$$U_{max} = 4W/N \tag{4}$$

where

U_{max} is the residual unbalance, in oz-in. (g-mm);

W is the journal static weight load, in lb (kg);

N is the maximum continuous speed, in rpm.

NOTE 1 ISO Grade 1.0 is approximately equivalent to $4W/N$.

NOTE 2 If the components for the equipment are relatively light in weight and/or operates at high speed, the limits given in this paragraph may not be achievable with commercial balancing machines.

• **6.7.5.2.2** If specified, after the final balancing of each assembled rotating element has been completed, a residual unbalance check shall be performed and recorded in accordance with the residual unbalance worksheet (Annex E).

6.7.5.2.3 During the shop test of the assembled machine, operating at maximum continuous speed or at any other speed within the specified operating speed range, the maximum allowable unfiltered peak amplitude of vibration in any plane measured on the bearing housing shall not exceed the value given in Table 3. At the trip speed of the driver, the vibration shall not exceed 150 % of these values.

6.7.5.2.4 Electrical and mechanical runout shall be determined by rotating the rotor through the full 360° supported in V blocks at the journal centers while measuring runout with a noncontacting vibration probe and a dial indicator at the centerline of each probe location and one probe tip diameter to either side.

NOTE The rotor runout determined in 6.7.4.1 generally will not be reproduced when the rotor is installed in a machine with hydrodynamic bearings. This is due to the effect of lubrication in all journal bearings. The rotor will assume a unique position in the bearings based on the slow roll speed and rotor weight.

6.7.5.2.5 Accurate records of electrical and mechanical runout, recorded in V blocks for the full 360° at each probe location, shall be included in the mechanical test report.

6.7.5.2.6 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 0.5 mil (10 µm) may be vectorially subtracted from the vibration signal measured during the factory test.

6.8 Bearings and Bearing Housings

6.8.1 General

6.8.1.1 Bearings shall be one of the following arrangements: rolling element radial and thrust, hydrodynamic radial and rolling element thrust, or hydrodynamic radial and thrust. Each shaft shall be supported by two radial bearings and one double acting axial (thrust) bearing that may or may not be combined with one of the radial bearings. Unless otherwise specified, the bearing type and arrangement shall be selected in accordance with the limitations in Table 4.

Table 4—Bearing Selection

Condition	Bearing Type and Arrangement
Radial and thrust bearing speed and life within limits for rolling element bearings and Fan energy density below limit	Rolling element radial and thrust
Radial bearing speed or life outside limits for rolling element bearings and Thrust bearing speed and life within limits and Fan energy density below limits	Hydrodynamic radial and rolling element thrust or Hydrodynamic radial and thrust
Radial and thrust bearing speed or life outside limits for rolling element bearings or Fan energy density above limit	Hydrodynamic radial and thrust

Limits are as follows.

a) Rolling element bearing speed: factor Nd_{m} shall not exceed the limits specified in Table 5, where d_{m} is the mean bearing diameter $(d + D)/2$, expressed in millimeters and N is the rotative speed, expressed in revolutions per minute.

b) Rolling element bearing life: basic rating L_{10h} per ISO 281 or ANSI/ABMA 9 of at least 55,000 hours for each bearing with continuous operation at rated conditions and at least 33,000 hours at maximum radial and axial loads and rated speed. No adjustment to L_{10} life shall be applied for bearing material properties or operating conditions.

NOTE In order to achieve a 3-year expected run length as required in 6.1.1, the indicated bearing system L_{10h} life for the fan bearings should be at least 32,444 hours. For a fan with two shaft bearings, each with an individual L_{10h} life of 55,000 hours, the indicated bearing system L_{10h} life is 34,648 hours, which is more than what is required for a 3-year run length.

c) Energy density: if the product of rated power, hp (kW), and rated speed, r/min, is 5.4 million (4 million) or greater, hydrodynamic radial and thrust bearings shall be used.

• **6.8.1.2** If specified, the actual radial and thrust loads for arrangement 3 and arrangement 7 bearings (see Annex C) shall be documented on the outline drawing.

Table 5—Element Bearing Limiting Nd_m/1000

Bearing Type	Oil Bath or Splash Lubricated	Circulating Oil or Oil Mist	Grease Lubricated (Note 4)	
			Bearings with or Without Shields or Bearings with No Seals	Bearings with Seals
Radial				
Single row deep groove ball bearing	500	500	380	230
Single row cylindrical roller bearings	450	500	380	Note 2
Single row tapered roller bearings	300	350	210	Note 2
Double row spherical roller bearings	300	350	200	Note 2
Double row angular contact ball bearings (two sets of balls in the same races)	300	360	225	145
Radial/Thrust				
Single row angular contact ball bearing (40° contact angle). (Note 1)	450	500	330	Note 2
Two single row angular contact ball bearings mounted back-to-back, face-to-face, or tandem, i.e. (Duplex) 40º contact angle. No preload. (Note 1)	360	450	270	Note 2
Tapered roller bearings	230	270	57	Note 2

$d_m = (d + D)/2$ (mm)

where

D is the outside diameter of outer race (mm);

d is the inside diameter of inner race (mm);

N is the rotational speed (rpm).

NOTE 1 The Nd_m limits for single row angular contact ball bearings and single row angular contact ball bearings mounted back-to-back, face-to-face, or tandem are based on machined cages as required by 6.8.2.7.1. The Nd_m limits for all other bearings in the table are based on pressed cage designs. Refer to 6.8.2.7 for bearing cage requirements.

NOTE 2 These bearings are generally not available with shields or seals.

NOTE 3 Rolling element bearing selected with Nd_m greater than that indicated in Table 5 requires purchasers and bearing manufacturer's approval with special consideration being given to cooling and confirmation that the temperature requirements of 6.9 are met.

NOTE 4 Limits for grease lubricated bearings and references to grease lubrication in 6.9 are presented for reference only since 6.9.1 requires bearings to be oil lubricated using mineral oil.

6.8.2 Rolling Element Bearings

6.8.2.1 Rolling element bearings shall be located, retained, and mounted in accordance with the following.

a) Bearings shall be located on the shaft using shoulders, collars, or other positive locating devices; snap rings and spring-type washers are not acceptable.

b) Bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametrical clearance, both in accordance with the recommendations of ABMA 7.

c) Bearings shall be mounted directly on the shaft; bearing carriers are not acceptable.

d) When tapered adapter sleeves are provided they shall meet the requirements of ABMA 8.

6.8.2.2 Internal Bearing Clearances

6.8.2.2.1 Single row deep-groove ball bearings shall have greater than normal initial internal clearance according to ISO 5753:1991, Group 3.

NOTE 1 For the purpose of this provision, ABMA 20, Group 3 is equivalent to ISO 5753:1991, Group 3.

NOTE 2 The internal clearance of a bearing under operating conditions (effective clearance) is usually smaller than the same bearing's initial clearance before being installed and operated. This is due to several factors including bearing shrink fit to the shaft or housing, the difference in temperature between the inner and outer rings, etc.

NOTE 3 Group 3 clearances are also known as C3 clearances.

6.8.2.2.2 The selection of the internal clearance group from ISO 5753:1991 for double row angular contact ball bearings, cylindrical roller bearings, double row self-aligning roller bearings, double row self-aligning ball bearings, and spherical roller bearings shall be determined for the individual application and stated on the datasheet.

NOTE 1 For the purpose of this provision, ABMA 20 groups are equivalent to ISO 5753:1991 groups.

NOTE 2 These clearances apply to nonpreloaded bearings and of a design such that they can take purely radial load (ISO 5753:1991).

NOTE 3 Single row tapered roller bearings and single row angular contact ball bearing mounted back-to-back or face-to-face clearance are not covered in ISO 5753:1991 and ABMA 20 since clearances for these bearings are set during assembly in the machine.

6.8.2.2.3 Single or double row bearings shall be of the deep groove Conrad type (no filling slots).

6.8.2.3 Four-point contact (split race) ball bearings and bearings with filling slots shall not be used.

6.8.2.4 The bearings shall be self-aligning.

6.8.2.5 Vendor shall advise on the datasheets the interference fit between the shaft and the inner ring of the bearing and the clearance between the outer ring of the bearing and the housing used in the design.

6.8.2.6 Preload for angular contact ball bearings and taper roller bearings shall be determined for the individual application and stated on the datasheet. Preload shall be set by grinding of the race faces rather than by spacers or springs.

NOTE Preload of angular contact ball bearings, and tapered roller bearings, is set during the installation of the bearing in the machine. The faces of these bearings are ground by the bearing manufacturer during manufacturing so as to result in the specified preload when finally assembled in the back-to-back or face to face configuration in the machine.

6.8.2.7 Rolling Element Bearing Cages

6.8.2.7.1 Unless otherwise specified or approved by the purchaser, double row or single row angular contact ball bearings and two single row ball bearings mounted back-to-back, face-to-face, or tandem shall be provided with machined cages.

6.8.2.7.2 Nonmetallic cages shall not be used.

6.8.2.7.3 Except as indicated in 6.8.2.7.1 and depending on availability, the following types of cages are preferred.

Bearing Type	Preferred Cage	Comments
Single row deep groove ball bearing (Conrad type)	Pressed steel (grease)	It is often thought that machined cages will eliminate most wear difficulties. In the case of single row deep groove ball bearings, pressed cages usually outlast machined cages when grease lubrication is used because of the difficulty in lubricating the riding surfaces of the machined cage. Pressed cages have larger clearances between the cage and balls, which allows better distribution of the grease. The pressed cages also do not take up as much room as the machined cage and therefore provide a larger reservoir for grease.
	Machined (oil)	More robust than pressed cages and not restricted by the above lubrication concerns. However, machined cages are generally not available in size 4 in. (100 mm) and below.
Single row cylindrical roller bearings	Machined (grease and oil lubricated)	More robust than pressed cage. The machined cage for this type of bearing has more reservoir capacity for grease than the single row deep groove bearing and is adequate to supply the required grease lubricant.
Double row spherical roller bearing	Machined (grease and oil lubricated)	More robust than pressed cage. The machined cage for this type of bearing has more reservoir capacity for grease than the single row deep groove bearing and is adequate to supply the required grease lubricant.
Tapered roller bearings	Pressed steel (grease and oil lubricated)	Manufacturers only make pressed gages for this type of bearing.

6.8.2.8 Bearing Boundary Dimensions

6.8.2.8.1 Radial ball and roller (cylindrical and spherical) bearing boundary dimensions shall be in accordance with ISO 15:1998 and ISO 582:1995. Tapered roller bearing boundary dimensions shall be in accordance with ISO 355:1977.

NOTE For the purpose of this provision, ABMA 20, Sections 2.0 and 5 are equivalent to ISO 15:1998 and ISO 582:1995, and ABMA 19.1 and ABMA 19.2 are equivalent to ISO 355:1977.

6.8.2.8.2 Radial ball and roller (cylindrical and spherical) bearing boundary tolerance class shall be in accordance with ISO 492:2002, Section 5.1—Normal Tolerance Class. Tapered roller bearing boundary tolerance shall be in accordance with ISO 492:2002, Section 5.2—Normal Tolerance Class.

NOTE 1 For the purpose of this provision, ABMA 20, Section 6—ABEC 1 (ball bearings) and RBEC 1 (roller bearings) are equivalent to ISO 492:2002, Section 5.1—Normal Tolerance Class.

NOTE 2 ABMA 19.1, Class K and ABMA 19.2 are equivalent to ISO 492:2002, Section 5.2—Normal Tolerance Class.

6.8.2.8.3 Bearing chamfers shall conform to ISO 582:1995 and ABMA 19.2.

NOTE For the purpose of this provision ABMA 20 and ABMA 19.1 are equivalent to ISO 582.

6.8.2.8.4 Finished steel balls for rolling element bearings shall be in accordance with ISO 3290:2001 with a maximum of Grade 16.

6.8.2.9 Rolling element thrust bearings shall be selected in accordance with the following.

a) A rolling element bearing may be a single row deep-groove ball bearing provided the combined axial thrust and radial load is within the capability of such a bearing and requirements of 6.8.1 are satisfied.

b) Where the loads exceed the capability of a single row deep-groove bearing, a spherical double row bearing shall be used.

6.8.3 Hydrodynamic Radial Bearings

6.8.3.1 Hydrodynamic radial bearings shall be split for ease of assembly, precision bored, and of the sleeve type, with steel-backed, babbitted replaceable liners or shells. These bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

6.8.3.2 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances to limit rotor vibration to the maximum specified amplitudes (see 6.7.4.4) while the equipment is operating at specified operating speeds, including operation at any critical frequency.

6.8.3.3 The liners or shells shall be in horizontally split housings and shall be replaceable without the removal of the casing, inlet box, pedestal, or coupling hub.

6.8.3.4 Sleeve bearings shall be self-aligning, supported on rigid pedestal(s) independent of the fan housing so as to be unaffected by vibration, differential expansion, or other forces from the fan housing.

6.8.4 Thrust Bearings

6.8.4.1 General

6.8.4.1.1 Thrust bearings shall be sized for continuous operation through the full operating range including the most adverse specified operating conditions. Calculation of the thrust load shall include but shall not be limited to the following factors:

a) fouling and variation in seal clearances at design and at twice the design internal clearances,

b) step thrust from all diameter changes,

c) external loads from the driver.

d) operation of fans with inlet and/or outlet conditions resulting in maximum aerodynamic forces such as a double inlet fan with one inlet 100 % blocked.

6.8.4.1.2 For gear-type couplings, the external thrust force shall be calculated from the following formula:

In SI units:

$$F = \frac{(0.25)(9500)P_\mathrm{r}}{N_\mathrm{r}D_\mathrm{p}}$$

In USC units:

$$F = \frac{(0.25)(63{,}000)P_\mathrm{r}}{N_\mathrm{r}D_\mathrm{p}}$$

where

F is the external thrust force, in lb (kN);

0.25 is the applied coefficient of gear tooth friction;

P_r is the rated power, in hp (kW);

N_r is the rated speed, in rpm;

D_p is the shaft diameter at the coupling, in in. (mm).

NOTE Shaft diameter is used to approximate gear coupling pitch diameter.

6.8.4.1.3 Thrust forces from metallic flexible element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

6.8.4.2 Hydrodynamic Thrust Bearings

6.8.4.2.1 Hydrodynamic thrust bearings shall be of the babbitted multiple-segment type, designed for equal thrust capacity in both directions and arranged for lubrication to each side. The thrust bearings shall be self-aligning.

6.8.4.2.2 Replaceable thrust collars shall be furnished and positively locked to the shaft to prevent fretting unless integral thrust collars are specified by the purchaser.

6.8.4.2.3 Both faces of thrust collars for hydrodynamic thrust bearings shall have a surface finish of not more than 32 μin. (0.8 μm) Ra, and the axial total indicated runout of either face shall not exceed 0.001 in. (25 μm) after the collar is mounted on the shaft.

6.8.4.2.4 Hydrodynamic thrust bearings shall be selected at no more than 50 % of the bearing manufacturer's maximum allowable load rating for all specified operating conditions. This may be increased to 80 % when considering one inlet completely closed on double-width, double-inlet fans, and start-up conditions for high-temperature fans.

6.8.5 Bearing Housings

6.8.5.1 Bearing housings shall be arranged so that bearings can be replaced without disturbing equipment driver or mounting.

• **6.8.5.2** Bearing housings for noncirculating oil-lubricated bearings shall be provided with tapped and plugged fill and drain openings at least NPS $^{1}/_{2}$, except antifriction bearing housings may have smaller openings. The housings shall be equipped with constant-level sight-feed oilers at least 8 oz (0.25 l) in size, with a positive level positioner (not a set screw). Heat-resistant glass containers (not subject to sunlight or heat-induced opacity or deterioration and protected by wire cages) shall be provided. If specified, the oilers shall meet the purchaser's preference. A permanent indication of the proper running oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings, or another durable means.

6.8.5.3 Housings for ring-oil-lubricated bearings shall be provided with plugged ports positioned to allow visual inspection of the oil rings while the equipment is running.

6.8.5.4 Bearing housings for circulating oil-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housing shall not exceed 50 °F (10 °C) under the most adverse specified operating conditions. The bearing outlet oil temperature shall not exceed 180 °F (80 °C). When the inlet oil temperature exceeds 120 °F (50 °C), special consideration shall be given to bearing design, oil flow, and allowable temperature rise. Oil connections on bearing housings shall be in accordance with 6.3.2.1 through 6.3.2.11.

6.8.5.5 Bearing housings shall be equipped with replaceable labyrinth-type end seals and deflectors where the shaft passes through the housing; lip-type seals shall not be used. The seals and deflectors shall be made of spark resistant materials. The design of the seals and deflectors shall effectively retain oil in the housings and prevent entry of foreign material into the housing.

6.8.5.6 Axially split-bearing housings shall have a metal-to-metal split joint whose halves are located by means of cylindrical dowels.

6.8.5.7 Sufficient cooling, including an allowance for fouling, shall be provided to maintain oil and bearing temperatures as follows, based on the specified operating conditions and an ambient temperature of 110 °F (40 °C).

a) For pressurized systems, oil outlet temperature below 160 °F (70 °C) and bearing metal temperatures (when bearing temperature sensors are supplied) less than 200 °F (93 °C). During shop testing, the bearing oil temperature rise shall not exceed 50 °F (28 °C).

b) For ring-oiled or splash systems, oil sump temperature below 180 °F (82 °C). During shop testing, the sump oil temperature rise shall not exceed 70 °F (40 °C).

NOTE Temperature stabilization may not be attained during the mechanical running test. If the purchaser desires temperature stabilization testing, this requirement should be stated in the inquiry and addressed by the vendor in the proposal.

6.8.5.8 For ambient conditions that exceed 110 °F (42 °C) or when the inlet oil temperature exceeds 120 °F (50 °C), special consideration shall be given to bearing design, oil flow, and allowable temperature rise.

6.8.5.9 Where water cooling is required, water jackets shall have only external connections between upper and lower housing jackets and shall not have gasketed connection joints that may allow water to leak into the oil reservoir. If cooling coils (including fittings) are used, they shall be of nonferrous, metallic material and shall have no internal pressure joints. Tubing or pipe shall have a minimum wall thickness of 0.040 in. (1 mm) and shall be at least 0.50 in. (12 mm) outside diameter.

6.8.5.10 All induced draft fans or process fans operating above 200 °F (95 °C) and without internal bearing cooling shall be supplied with heat slingers (with safety guards) located between the fan housing and/or inlet box(es) and the adjacent bearing(s). The design of the heat slingers and the shaft mounting arrangement shall be described in the vendor's proposal.

6.8.5.11 The requirements of 6.8.5.12 through 6.8.5.16 apply if oil mist lubrication is specified.

6.8.5.12 An oil mist inlet connection, $^1/_4$ in. (6 mm) nominal pipe size shall be provided in the top half of the bearing housing. The pure oil or purge oil mist fitting connections shall be located so that oil mist will flow through the antifriction bearings. There shall be no internal passages to short-circuit oil mist from inlet to vent. If bearings are of the sleeve type, the connections for the condensing oil mist fittings shall be located over the bearings so that makeup oil will drip into the bearings.

6.8.5.13 A vent connection NPS $^1/_4$ shall be provided on the housing or end cover for each of the spaces between the antifriction bearings and the housing shaft closures. Housings with only sleeve-type bearings shall have the vent located near the end of the housing.

6.8.5.14 When pure oil or purge oil mist lubrication is specified, shielded or sealed bearings shall not be used.

6.8.5.15 When pure oil mist lubrication is specified, oil rings or flingers (if any) and constant-level oilers shall not be provided, and a mark indicating the oil level is not required. When purge oil or condensing oil mist lubrication is specified, these items shall be provided and the oiler shall be piped so that it is maintained at the internal pressure of the bearing housing.

NOTE Pure oil mist is applied only to antifriction bearings.

6.8.5.16 The oil mist supply and drain fittings shall be provided by the purchaser.

6.8.5.17 Flat surfaces at least 1 in. (25 mm) in diameter shall be supplied for the location of magnetic-based vibration measuring equipment. The surfaces shall be located in the horizontal, vertical, and axial planes.

6.8.6 Requirements for Special Purpose Fans

6.8.6.1 Bearing Housings

6.8.6.1.1 Bearing housings for noncirculating oil-lubricated bearings shall be provided with tapped and plugged fill and drain openings at least NPS $^1/_2$, except antifriction bearing housings may have smaller openings. The housings shall be equipped with constant-level sight-feed oilers at least 8 oz (0.25 l) in size, with a positive level positioner (not a set screw). Heat-resistant glass containers (not subject to sunlight or heat-induced opacity or deterioration and protected by wire cages) shall be provided. When specified, the oilers shall meet the purchaser's preference. A permanent indication of the proper running oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings, or another durable means.

6.8.6.1.2 All bearing housings for induced draft fans or process fans operating above 300 °F (150 °C) shall have provisions for water cooling.

• **6.8.6.1.3** If specified, provisions for a noncontacting speed measurement probe or a mechanical type speed activated switch shall be provided. If a mechanical type device is provided, it shall be supported from the fan bearing pedestal.

NOTE This speed sensor or switch may be used to monitor speed on variable speed drives, start the backup drive on dual-drive applications, or shut down on overspeed.

• **6.8.6.1.4** If specified, provisions for bearing oil temperature indicators shall be provided.

• **6.8.6.1.5** If specified, bearing housings shall have a threaded connection(s) for permanently mounting vibration transducers in accordance with API 670. When metric fasteners are supplied, the threads shall be M8. The spotface and drilling are to be per Figure 5 and located on the top of each bearing housing.

• **6.8.6.1.6** If specified, hydrodynamic bearing housings shall have provisions for mounting two radial vibration probes in each bearing housing and a one-event-per-revolution probe. The probe installation shall be as specified in API 670.

6.8.6.1.7 Bearing housing mounting surfaces shall be machined in a continuous plane parallel to the bearing bore.

6.8.6.1.8 Bearing housings shall be drilled with pilot holes for use in final doweling.

6.9 Lubrication

6.9.1 Unless otherwise specified, hydrodynamic bearings and bearing housings shall be arranged for oil lubrication using a mineral oil in accordance with ISO 8068, Type AR.

6.9.2 Antifriction bearings may be either static oil, circulating oil, oil mist, or grease lubricated, depending on the application. In order to select the proper lubrication method, the vendor shall perform a thermal analysis of the

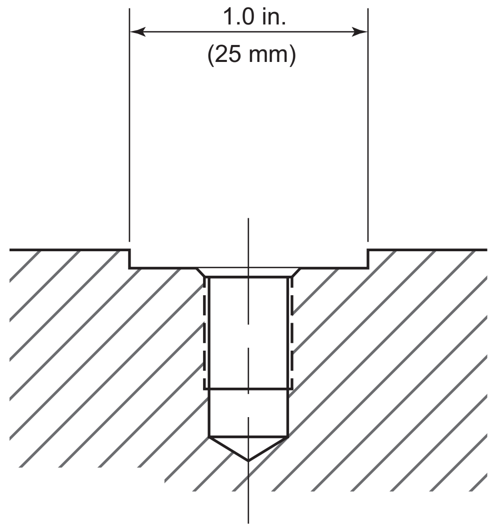


Figure 5—Threaded Connection for Vibration Transducer

bearings taking into account the heat conducted by the shaft in hot gas applications and the maximum specified ambient temperature. The lubrication method will be reviewed and approved by the purchaser. The requirements of 6.9.2.1 through 6.9.2.3 shall apply.

6.9.2.1 For static oil or grease lubrication the calculated maximum bearing housing temperature shall not exceed 180 °F (80 °C).

6.9.2.2 Grease lubricated bearings shall not exceed the bearing supplier's published maximum allowable speed for grease lubrication.

6.9.2.3 The vendor shall provide in the service manual a lubricant specification, a recommended relubrication interval, and a recommended clean and repack interval for the specific application.

6.9.3 If specified or required by the equipment, a pressurized oil system shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the bearings of the driver and of the driven equipment (including any gear).

6.9.4 Where oil is supplied from a common system to two or more components of a machinery train (such as a fan, a gear, and a motor), the vendor having unit responsibility shall ensure compatibility of type, grade, pressure, and temperature of oil for all equipment served by the common system.

NOTE Compatibility of lube oil requirements needs to be mutually agreed among the user and all vendors supplying equipment served by the common system. In some cases there can be significant differences in individual component needs. For example, a gear may need high viscosity and a turbine may need a conventional mineral oil. In such cases it may be necessary to change the design of a component or to provide separate oil systems.

6.9.5 Pressurized oil systems shall be supplied in accordance with API 614, Ch. 1 and Ch. 3.

NOTE The API 614 general purpose lube oil system contains numerous options for the specifier's consideration. Refer to Annex F for the API 673 default general purpose lube oil system and recommended options.

6.9.6 Oil disks and oil rings shall be metal and shall have an operating submergence of $^1/_8$ in. to $^1/_4$ in. (3 mm to 6 mm) above the lower edge of the disk or above the lower edge of the bore of an oil ring. Oil disks shall have mounting hubs to maintain concentricity and shall be positively secured to the shaft.

6.9.7 The vendor shall state in the operating manual the amount of and the specifications for all required lubricants.

6.9.8 If specified for ring or disc lubricated bearings, thermostatically controlled heating devices shall be provided in the bearing housings. The heating devices shall have sufficient capacity to heat the oil in the bearing housing from the specified minimum site ambient temperature to the vendor's minimum required temperature in 4 hours. If an electric immersion heater is used, the watt density shall not exceed 15 watts/in.^{2} (2 watts/cm^2).

6.9.9 Special Purpose Applications

Pressurized oil systems shall be supplied in accordance with API 614, Ch. 1 and Ch. 2.

6.10 Materials

6.10.1 General

6.10.1.1 Materials of construction shall be selected for the operating and site environmental conditions specified.

6.10.1.2 Materials of construction shall be the manufacturer's standard for the specified operating conditions, except as required or prohibited by the datasheets or this standard (see 7.6) for requirements for auxiliary piping materials). The metallurgy of all major components shall be clearly stated in the vendor's proposal. The corrosion allowance of carbon steel plate shall be $^1/_8$ in. (3 mm).

6.10.1.3 The material specification of all major components shall be clearly stated in the vendor's proposal. Materials shall be identified by reference to applicable international standards, including the material grade. When no such designation is available, the vendor's material specification—giving physical properties, chemical composition, and test requirements—shall be included in the proposal.

NOTE Where international standards are not available, internationally recognized national or other standards may be used.

• **6.10.1.4** If specified, copper or copper alloys shall not be used for parts of machines or auxiliaries in contact with process fluids. Nickel-copper alloy (UNS N04400), bearing babbitt, and precipitation-hardened stainless steels are excluded from this requirement.

NOTE Certain corrosive fluids in contact with copper alloys have been known to form explosive compounds.

6.10.1.5 The vendor shall specify the optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal.

NOTE The purchaser can specify additional optional tests and inspections—especially for materials used for critical components or in critical services.

6.10.1.6 External parts that are subject to rotary or sliding motions (such as control linkage joints and adjustment mechanisms) shall be of corrosion-resistant materials suitable for the site environment.

6.10.1.7 Minor parts such as nuts, springs, washers, gaskets, and keys shall have corrosion resistance at least equal to that of specified parts in the same environment.

• **6.10.1.8** The purchaser shall specify any corrosive agents (including trace quantities) present in the process fluids and in the site environment, including constituents that may cause stress corrosion cracking.

NOTE Typical agents of concern are hydrogen sulfide, amines. chlorides, cyanide. fluoride, naphthenic acid, and polythionic acid.

6.10.1.9 If austenitic stainless steel parts exposed to conditions that may promote intergranular corrosion are to be fabricated, hard faced, overlaid or repaired by welding, they shall be made of low-carbon or stabilized grades.

NOTE Overlays or hard surfaces that contain more than 0.10 % carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.

6.10.1.10 Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification and compatible with the specified process fluid(s).

NOTE The required torque values to achieve the necessary bolt preload will vary considerably depending if antiseizure compounds are used on the threads (6.3.2.11).

- **6.10.1.11** The purchaser shall specify the amount of wet H_2S that can be present, considering normal operation, start-up, shutdown, idle standby, upsets, or unusual operating conditions.

In many applications, small amounts of wet H_2S are sufficient to require materials resistant to sulfide stress corrosion cracking. If trace quantities of wet H_2S are known to be present or if there is any uncertainty about the amount of wet H_2S that can be present, the purchaser should consider specifying that reduced-hardness materials are required.

- **6.10.1.12** The purchaser shall specify if reduced-hardness materials are required.

6.10.1.13 If reduced-hardness materials are specified in 6.10.1.12, they shall be supplied in accordance with NACE MR0103.

NOTE NACE MR0103 applies to oil refineries, LNG plants, and chemical plants. NACE MR0103 applies to materials potentially subject to sulfide stress corrosion cracking.

- **6.10.1.14** If specified, reduced-hardness materials shall be supplied in accordance with ISO 15156-1.

NOTE 1 For the purposes of this provision, ANSI/NACE MR0175 is equivalent to ISO 15156-1.

NOTE 2 ISO 15156 (all parts), which is the equivalent of ANSI/NACE MR0175, applies to material potentially subject to sulfide and chloride stress corrosion cracking in oil and gas production facilities and natural gas sweetening plants.

6.10.1.15 If reduced-hardness materials are specified, ferrous material not covered by NACE MR0103 or ANSI/NACE MR0175 (ISO 15156-1) shall have a yield strength not exceeding 90,000 psi (620 N/mm^2) and a hardness not exceeding HRC 22. Components that are fabricated by welding shall be postweld heat treated, if required, so that both the welds and heat-affected zones meet the yield strength and hardness requirements.

6.10.1.16 The vendor shall select materials to avoid conditions that may result in electrolytic corrosion. Where such conditions cannot be avoided, the purchaser and the vendor shall agree on the material selection and any other precautions necessary.

NOTE When dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples that can result in serious corrosion of the less noble material may be created. The *NACE Corrosion Engineer's Reference Book* is one resource for selection of suitable materials in these situations.

6.10.1.17 Materials, casting factors, and the quality of any welding shall be equal to those required by ASME *Boiler and Pressure Vessel Code (BPVC), Section VIII, Division 1*. The manufacturer's data report forms, as specified in the *Code*, are not required.

NOTE For impact requirements refer to 6.10.3.

6.10.1.18 Low-carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice are acceptable. Steel made to a course austenitic grain size practice (such as ASTM A515) shall not be used.

6.10.1.19 O-ring materials shall be compatible with all specified services.

NOTE Agents affecting elastomer selection include ketones, ethylene oxide, sodium hydroxide, methanol, benzene, and solvents.

6.10.2 Welding

6.10.2.1 All welding, including weld repairs, shall be performed by welders, welder operators, and procedures qualified in accordance with the specifications of AWS D1.1/D1.1M:2006 for housings and structural components and AWS D14.6/D14.6M:2005 for rotating elements.

6.10.2.2 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with AWS D14.6/D14.6M:2005, Section 8 (also see 6.10.1.9).

6.10.2.3 Repairs by welding on rotating or stationary elements shall be performed in accordance with AWS D14.6/D14.6M:2005, Section 9.

6.10.2.4 All butt joints (groove welds) on rotating elements shall be continuous and full penetration welds.

6.10.2.5 Accessible surfaces of rotating element welds shall be inspected by magnetic particle or liquid penetrant examination before and after postweld heat treatment.

6.10.2.5.1 Full penetration welds that require back gouging from the root side shall be inspected by magnetic particle or liquid penetrant examination after back gouging, prior to subsequent welding.

6.10.3 Low-temperature Service

• For operating temperatures below –20 °F (–20 °C) or, if specified by the purchaser for other low ambient temperatures, steels shall have, at the lowest specified temperature, an impact strength sufficient to qualify under the minimum Charpy V-notch impact energy requirements of ASME *BPVC*, *Section VIII, Division 1*, UG-84. For materials and thicknesses not covered by the ASME *Code*, the purchaser shall specify the requirements on the datasheet.

6.10.4 Additional Requirements for Special Purpose Fans

6.10.4.1 Positive Material Identification (PMI)

6.10.4.1.1 PMI testing shall be in accordance with 6.10.4.1.2 through 6.10.4.1.8.

• **6.10.4.1.2** If specified, the following alloy steel items shall be subject to PMI testing:

a) fan casing,

b) shafts,

c) impellers,

d) shaft sleeves,

e) bearing oil film surface,

f) alloy claddings and weld overlays,

g) casing joint bolting (studs and nuts),

h) inlet guide vanes,

i) other components as specified.

• **6.10.4.1.3** In addition to the components outlined in 6.10.4.1.2 other materials, welds, fabrications, and piping shall be PMI tested as specified.

6.10.4.1.4 When PMI testing has been specified for a fabrication, the components comprising the fabrication, including welds, shall be checked after the fabrication is complete except as permitted in 6.10.4.1.5. Testing may be performed prior to any heat treatment.

6.10.4.1.5 Unique (nonstock) components such as impellers, turbine blading, and shafts may be tested after manufacturing and prior to rotor assembly.

6.10.4.1.6 When PMI is specified, techniques providing quantitative results shall be used.

NOTE 1 PMI test methods are intended to identify alloy materials and are not intended to establish the exact conformance of a material to an alloy specification.

NOTE 2 Additional information on PMI testing can be found in API 578.

NOTE 3 PMI is used to verify that the specified materials are used in the manufacturing, fabrication, and assembly of components.

6.10.4.1.7 Mill test reports, material composition certificates, visual stamps, or markings shall not be considered as substitutes for PMI testing.

6.10.4.1.8 PMI results shall be within the material specification limits, allowing for the measurement uncertainty (inaccuracy) of the PMI device as specified by the device manufacturer.

6.11 Nameplates and Rotation Arrows

6.11.1 A nameplate shall be securely attached at a readily visible location on the equipment and on any other major piece of auxiliary equipment.

6.11.2 Rotation arrows shall be cast-in or attached to each major item of rotating equipment at a readily visible location.

6.11.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper (UNS N04400) alloy. Attachment pins shall be of the same material. Welding is not permitted.

6.11.4 The following data (where relevant) shall be clearly stamped or engraved on the nameplate:

a) vendor's name;

b) serial number;

c) size, type, and model;

d) rated capacity;

e) purchaser item number or other reference;

f) lateral critical speed.

The purchaser shall specify whether SI or USC units are to be shown.

NOTE Lateral critical speeds determined from running tests shall be stamped on the nameplate followed by the word "TESTS." Critical speeds predicted by calculation up to and including the first critical speed above trip speed and not identifiable by test shall be stamped on the nameplate followed by the abbreviation "CALC."

7 Accessories

7.1 Drivers

7.1.1 General

7.1.1.1 The driver shall be of the type specified, shall be sized to meet the maximum specified operating conditions, including external gear and coupling losses, and shall be in accordance with applicable specifications, as stated in the inquiry and order. The driver shall operate under the utility and site conditions specified in the inquiry.

7.1.1.2 The driver shall be sized to accept any specified process variations such as changes in the pressure, temperature, or properties of the fluids handled and plant start-up conditions.

NOTE Consideration should be given to sizing forced draft fan motor drivers for undampered fan performance at minimum ambient temperature. Induced draft fan driver considerations include possible variations in operating temperature and gas density from start-up through normal operation.

7.1.1.3 The driver shall be capable of starting under the conditions specified and the starting method shall be agreed by the purchaser and the vendor. The driver's starting-torque capabilities shall exceed the speed-torque requirements of the driven equipment.

7.1.1.4 The supporting feet of drivers with a weight greater than 500 lb (250 kg) shall be provided with vertical jackscrews.

7.1.2 Motors

7.1.2.1 Motor drives shall conform to internationally recognized standards such as API 541, API 546, or API 547 as applicable. Motors that are below the power scope of API 541 or API 546 shall be in accordance with IEEE 841 or IEC 60034. Equipment driven by induction motors shall be rated at the actual motor speed available for the rated load specified. Motor drives shall have power ratings, including service factor (if any) at least equal to the percentages of power at fan rated conditions given in Table 6. The power at rated conditions shall not exceed motor nameplate without service factor. Where it appears this will lead to uneconomical oversizing of the drive, an alternative proposal shall be submitted for the purchaser’s approval. Electric motor drivers shall be rated with a 1.0 service factor. The motor rating shall be at least 110 % of the greatest power required (including gear and coupling losses) for any of the specified operating conditions. Consideration shall be given to the starting conditions of both the driver and driven equipment and the possibility that these conditions may be different from the normal operating conditions.

NOTE The 110 % applies to the design phase of a project. After testing, this margin might not be available because of performance tolerances of the driven equipment.

7.1.2.2 The purchaser shall specify the type of motor and its characteristics and accessories, including but not limited to the following:

a) electrical characteristics;

b) starting conditions (including the expected voltage drop on starting);

c) the type of enclosure;

d) the SPL;

e) the area classification, based on API 500A or equivalent international standard;

f) the type of insulation;

g) the required service factor;

h) the ambient temperature and elevation above sea level;

i) transmission losses;

j) temperature detectors, vibration sensors, and heaters specified;

k) auxiliaries (such as motor-generator sets, ventilation blowers, and instrumentation);

l) vibration acceptance criteria;

m) use in VFD applications.

7.1.2.3 The motor's starting torque shall meet the requirements of the driven equipment, at a reduced voltage of 80 % of the normal voltage, or such other value as may be specified, and the motor shall accelerate to full speed within 30 seconds or such other period of time agreed upon by the purchaser and the vendor.

7.1.3 Steam Turbines

• **7.1.3.1** Steam turbine drivers shall conform to API 611 or, if specified for special purpose applications, to API 612. Steam turbine drivers rated power shall not be less than 110 % of the maximum power requirement of the driven equipment (including any gear and coupling losses) when operating at any of the specified operating conditions.

NOTE 1 The 110 % applies to the design phase of the project. After testing, this margin might not be available because of performance tolerances of the driven equipment.

NOTE 2 Steam turbines are normally required to be capable of producing rated power at minimum inlet and maximum outlet (minimum energy) steam conditions. Fan test block power requirements can be significantly higher than normal operating power and can result in oversizing the turbine. Consideration should be given to limiting the 110 % power and/or the minimum steam requirements for test block conditions.

Table 6—Power Ratings for Motor Drives

Motor Nameplate Rating		Percent of Rated Fan Power
hp	kW	
≤25	≤18.5	125
30 to 75	22 to 55	115
≥100	≥75	110

• 7.1.4 Gear Units

Gear units shall conform to API 677 or, if specified for special purpose applications, to API 613.

7.2 Couplings

7.2.1 Unless otherwise specified, nonlubricated flexible element couplings and guards between drivers and driven equipment shall be supplied by the fan manufacturer.

NOTE Dual drives may require overrunning clutches that must also be mutually agreed between purchaser and fan vendor with appropriate driver vendor input for “standby” lockout devices, overhanging load, etc. Other types of couplings may be required for some applications.

7.2.2 Couplings for general purpose applications shall be all-metal flexible element, spacer-type couplings manufactured to meet AGMA 9000, Class 9 and shall comply with the following.

a) Flexible elements shall be of corrosion-resistant material.

b) Couplings shall be designed to retain the spacer if a flexible element ruptures.

c) Coupling hubs shall be steel.

d) The distance between the driven and driver shaft ends (distance between shaft ends) shall be at least 7 in. (178 mm) and shall permit removal of the coupling, bearings, seal, and rotor, as applicable, without disturbing the driven equipment or inlet and exhaust ductwork.

e) Where servicing of the shaft seal requires removal of the hub, the hub shall be mounted with a taper fit.

f) Provision shall be made for the attachment of alignment equipment without the need to remove the spacer or dismantle the coupling in any way.

NOTE One way of achieving this is to provide at least 1 in. (25 mm) of bare shaft between the coupling and the bearing housing where alignment brackets may be located.

• **7.2.3** If specified, couplings shall be balanced to ISO 19401, Grade G6.3.

7.2.4 Flexible couplings shall be keyed to the shaft. Keys, keyways, and fits shall conform to AGMA 9002, Commercial Class.

7.2.5 Flexible couplings with cylindrical bores shall be mounted with an interference fit. Cylindrical shafts shall comply with AGMA 9002 and the coupling hubs shall be bored to the following tolerances (ISO 286-2):

a) for shafts of 2 in. (50 mm) diameter and smaller—Grade N7,

b) for shafts larger than 2 in. (50 mm) diameter—Grade N8.

7.2.6 Coupling hubs shall be finished with tapped puller holes at least 0.375 in. (10 mm) diameter to facilitate removal. Where a keyway extends beyond the fitted coupling hub, the supplied shaft key shall be fitted to the shaft keyway and stepped up at the hub.

7.2.7 Information on shafts, keyway dimensions (if any), and shaft end movements resulting from end play and/or thermal effects shall be furnished to the vendor supplying the coupling.

NOTE This information is normally furnished by the vendor of the driven equipment or the driver vendor.

7.2.8 The coupling and coupling-to-shaft juncture shall be designed and manufactured to be capable of transmitting power at least equal to the power rating of the motor including service factor. See 6.5.8 for torque requirements.

7.2.9 Each coupling shall have a coupling guard that is removable without disturbing the coupled elements and shall meet the requirements of 7.2.9.1 through 7.2.9.3.

7.2.9.1 Coupling guards shall sufficiently enclose the coupling and the shafts to prevent personnel from contacting moving parts during operation of equipment train. Allowable access dimensions shall comply with specified standards, such as ISO 14120, EN 953, or ASME B15.1.

7.2.9.2 Guards shall be constructed with sufficient rigidity to withstand a 200 lbf (900 N) static point load (or force) in any direction without the guard contacting moving parts.

• **7.2.9.3** Guards shall be fabricated from solid sheet or plate with no openings. Guards fabricated from expanded metal or perforated sheets may be used if the size of the openings does not exceed 0.375 in. (10 mm). Guards shall be constructed of steel, brass, or nonmetallic (polymer) materials. Guards of woven wire shall not be used. If specified, or if required for the specified area classification, nonsparking guards of agreed material shall be supplied.

7.2.10 Additional Requirements for Special Purpose Fans

If specified, couplings for special purpose applications shall conform to API 671. The make, type, and mounting arrangement shall be agreed by the purchaser and vendors of the driver and driven equipment.

7.3 Belt Drives

7.3.1 Belt drives shall only be used for equipment of 100 BHP (75 kW) or less and require purchasers approval. Unless otherwise specified, timing belts and sheaves shall be provided. All belts shall be of the static-conducting type and shall be oil resistant. The drive service factor shall not be less than 1.75 times the driver nameplate power rating. If other than timing type belts are used, the details of belt tension, center distance, belt wrap, and testing shall be mutually agreed by the vendor and purchaser.

NOTE Oil resistant belts require a core of neoprene or equivalent material.

7.3.2 The vendor shall provide a positive belt-tensioning device. This device shall incorporate a lateral adjustable base with guides and hold-down bolts, two belt-tensioning screws, and locking devices. All bearing lubrication points shall be accessible.

7.3.3 If a belt drive is to be used, the vendor who has unit responsibility shall inform other manufacturers of the connected equipment. The other manufacturer(s) shall be provided with the radial load resulting from the belt drive. The drive manufacturer shall take into account the radial load and torque variation conditions and shall provide bearings with a life at least equivalent to that specified in 6.8.1.

7.3.4 Belt drives shall meet the requirements of 7.3.4.1 through 7.3.4.7.

7.3.4.1 The distance between the centers of the sheaves shall not be less than 1.5 times the diameter of the larger sheave.

7.3.4.2 The belt wrap (contact) angle on the smaller sheave shall not be less than 140°.

7.3.4.3 The shaft length on which the sheave hub is fitted shall be at least equal to the width of the sheave hub.

7.3.4.4 The length of a shaft key used to mount a sheave shall be equal to the length of the sheave bore.

7.3.4.5 Unless otherwise agreed or specified, the sheave shall be mounted on a tapered adapter bushing.

7.3.4.6 To reduce moment on shafts due to belt tension, the sheave overhang distance from the adjacent bearing shall be minimized.

7.3.4.7 Sheaves shall meet the balance requirements of ANSI S2.19, Grade 6.3 (ISO 1940).

7.4 Mounting Plates

7.4.1 General

• **7.4.1.1** The equipment shall be furnished with soleplates or baseplates, as specified.

7.4.1.2 Mounting plates (baseplates and soleplates) shall comply with the requirements of 7.4.1.3 through 7.4.1.19.

7.4.1.3 All machinery mounting surfaces on the fan bearing pedestals and mounting plates shall meet the following criteria.

a) They shall be machined after the baseplate is fabricated.

b) They shall be machined to a finish of 250 µin. (6.3 µm) Ra or better.

c) They shall have each mounting surface machined within a flatness of 0.0005 in. per linear ft (40 µm per linear m) of mounting surface.

d) Mounting surfaces for each piece of equipment shall be machined in the same horizontal plane within 0.001 in. (25 µm) to prevent a soft foot.

e) Mounting planes for different equipment shall be shall be machined parallel to each other within 0.002 in. (50 µm).

7.4.1.4 All machinery mounting surfaces on mounting plates shall extend at least 1 in. (25 mm) beyond the outer three sides of the equipment feet.

7.4.1.5 Outside exposed corners of mounting plates which are in contact with the grout shall have 2 in. (50 mm) minimum radiused outside corners (in the plan view). See Figure 6, Figure 7, Figure 8, and Figure 9. Embedded edges shall be rounded.

7.4.1.6 Mounting plate(s) which support equipment weighing more than 500 lb (225 kg) shall be furnished with axial and lateral jackscrews the same size or larger than the mounting foot vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates so the lugs do not interfere with the removal or installation of the equipment, jackscrews, or shims. If the equipment is too heavy to use jackscrews for alignment, other means shall be provided.

7.4.1.7 Unless otherwise specified, epoxy grout shall be used for machines mounted on concrete foundations. The vendor shall blast clean in accordance with SSPC SP6 (ISO 8501, Grade Sa2), all grout contact surfaces of the mounting plates and coat these surfaces with a primer compatible with epoxy grout. The manufacturer shall advise the purchaser the actual primer used.

NOTE Epoxy primers have a limited life after application. The grout manufacturer should be consulted to ensure proper field preparation of the mounting plate for satisfactory bonding of the grout.

7.4.1.8 Anchor bolts shall not be used to fasten equipment to the mounting plates.

7.4.1.9 The purchaser shall specify the manufacturer of the epoxy grout to be used for field installation.

7.4.1.10 Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates shall be supplied with leveling screws. All machinery mounting surfaces shall be treated with a rust preventive material immediately after machining.

7.4.1.11 Alignment shims shall be provided by the vendor in accordance with API 686, Ch. 7 and shall straddle the hold-down bolts and vertical jackscrews and be at least 0.25 in. (6 mm) larger on all sides than the equipment feet.

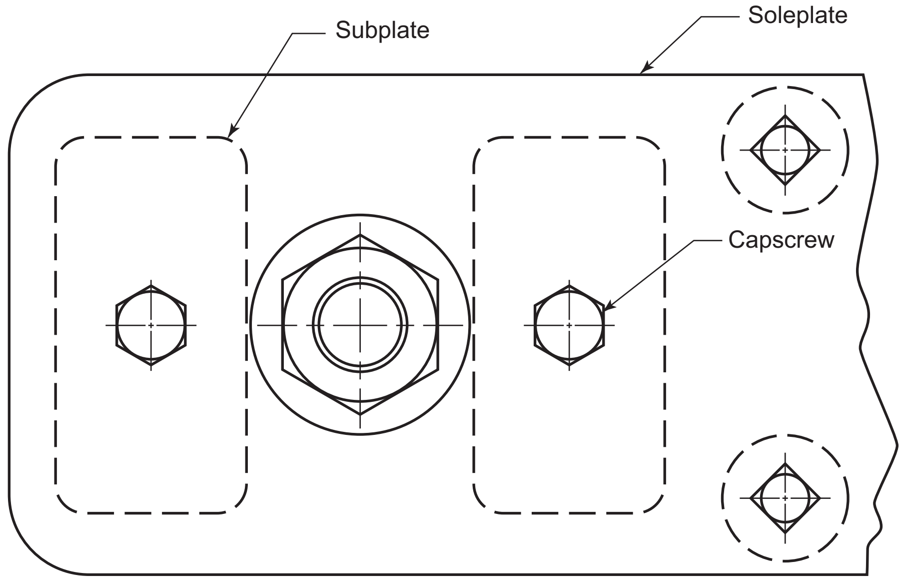
7.4.1.12 Unless otherwise specified, anchor bolts shall be furnished by the purchaser.

7.4.1.13 Hold-down bolts used to attach the equipment to the mounting plates, and all jackscrews, shall be supplied by the vendor.

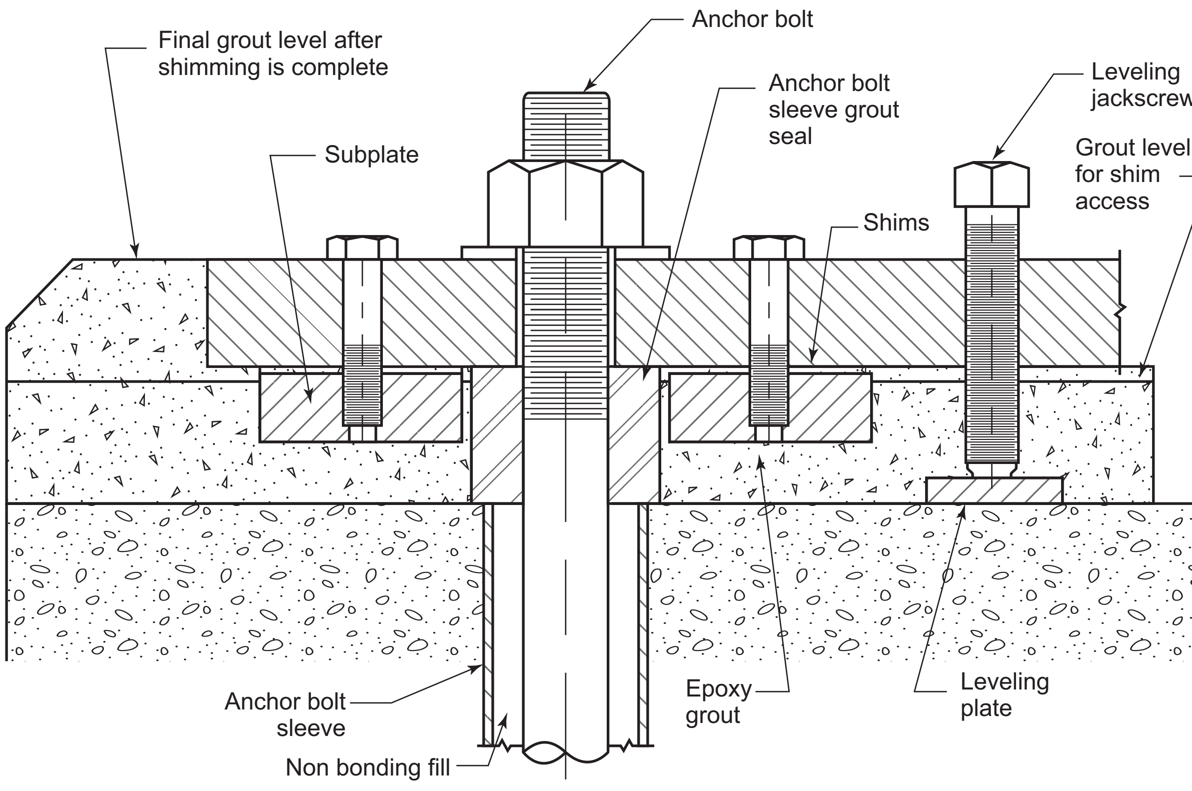
7.4.1.14 Equipment shall be designed for installation in accordance with API 686.

7.4.1.15 Grouted mounting plates shall be adequately sized to limit the static loading to 100 psi (680 kN/m^2) on the grout.

7.4.1.16 Diametrical clearance between anchor bolts and the anchor bolt holes in the mounting plates shall be a minimum of 0.25 in. (6 mm).



Top view of foundation at foundation bolt



Cross-section of foundation at foundation bolt

Figure 6—Typical Mounting Plate Arrangement 1

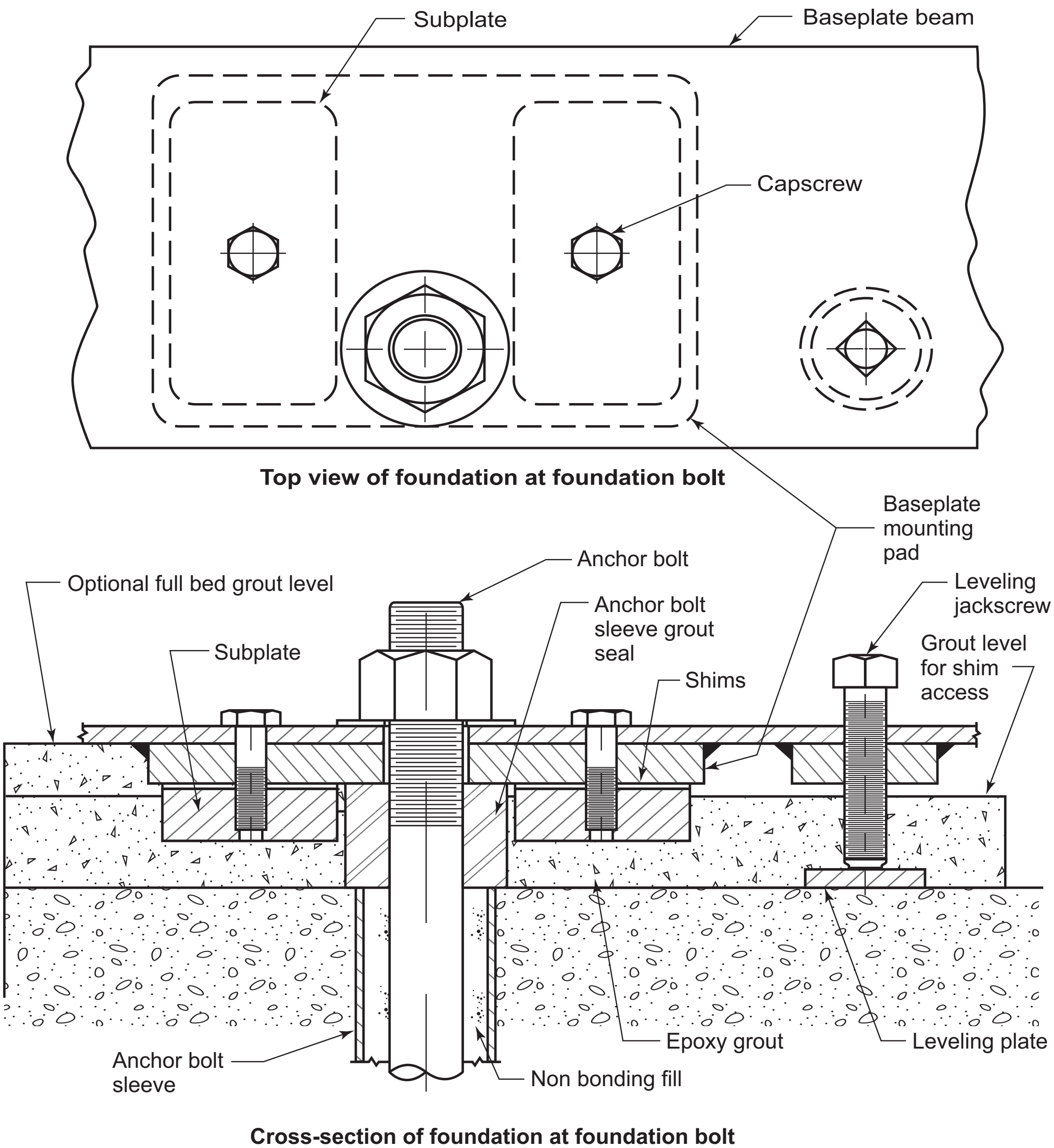
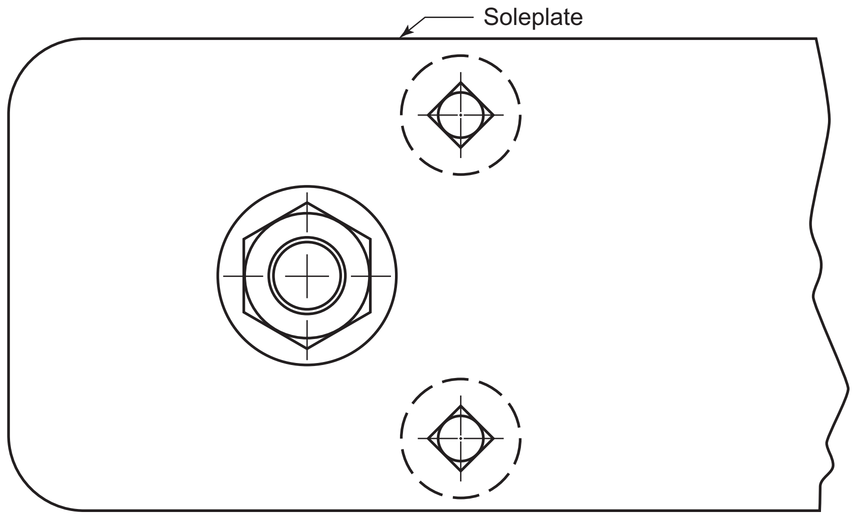


Figure 7—Typical Mounting Plate Arrangement 2

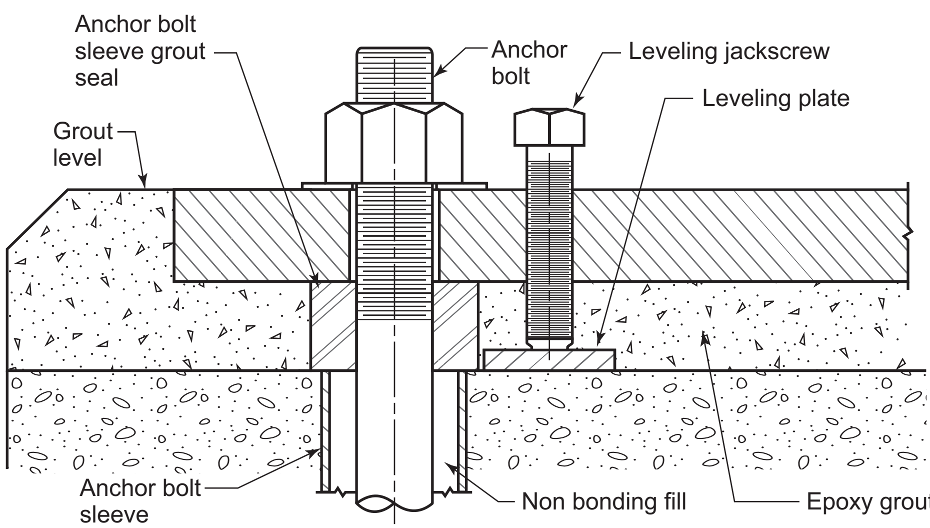
7.4.1.17 Adequate working clearance shall be provided at the hold-down and jack bolt locations to allow the use of standard socket or box wrenches, to achieve the specified torque.

- **7.4.1.18** If specified, the base of the bearing pedestals shall be drilled with pilot holes for use in final dowelling.

- **7.4.1.19** If specified, bearing pedestals shall be suitably designed and provided with adequate fill and vent holes to allow filling all interior spaces with grout. To the extent practical, the requirements of 7.4.2.6 should be followed.



Top view of foundation at foundation bolt



Cross-section of foundation at foundation bolt

Figure 8—Typical Mounting Plate Arrangement 3

7.4.2 Baseplates

7.4.2.1 If a baseplate (subbase in AMCA terminology) has been specified, the purchaser shall indicate the major equipment to be mounted on it. A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor mutually agree that it may be fabricated in multiple sections. Multiple-section baseplates shall have machined and doweled mating surfaces to ensure accurate field reassembly.

7.4.2.2 Baseplates shall be furnished with a gutter type drain 3 in. (75 mm) wide and 2 in. (50 mm) deep around the circumference of the base deck. The gutter shall be sloped at least 1 in 120, where a tapped drain opening of at least 2 NPS (DN 50) shall be located to effect complete drainage.

7.4.2.3 All joints, including deck plate to structural members, shall be continuously seal-welded on both sides to prevent crevice corrosion. Stitch welding, top or bottom, is unacceptable.

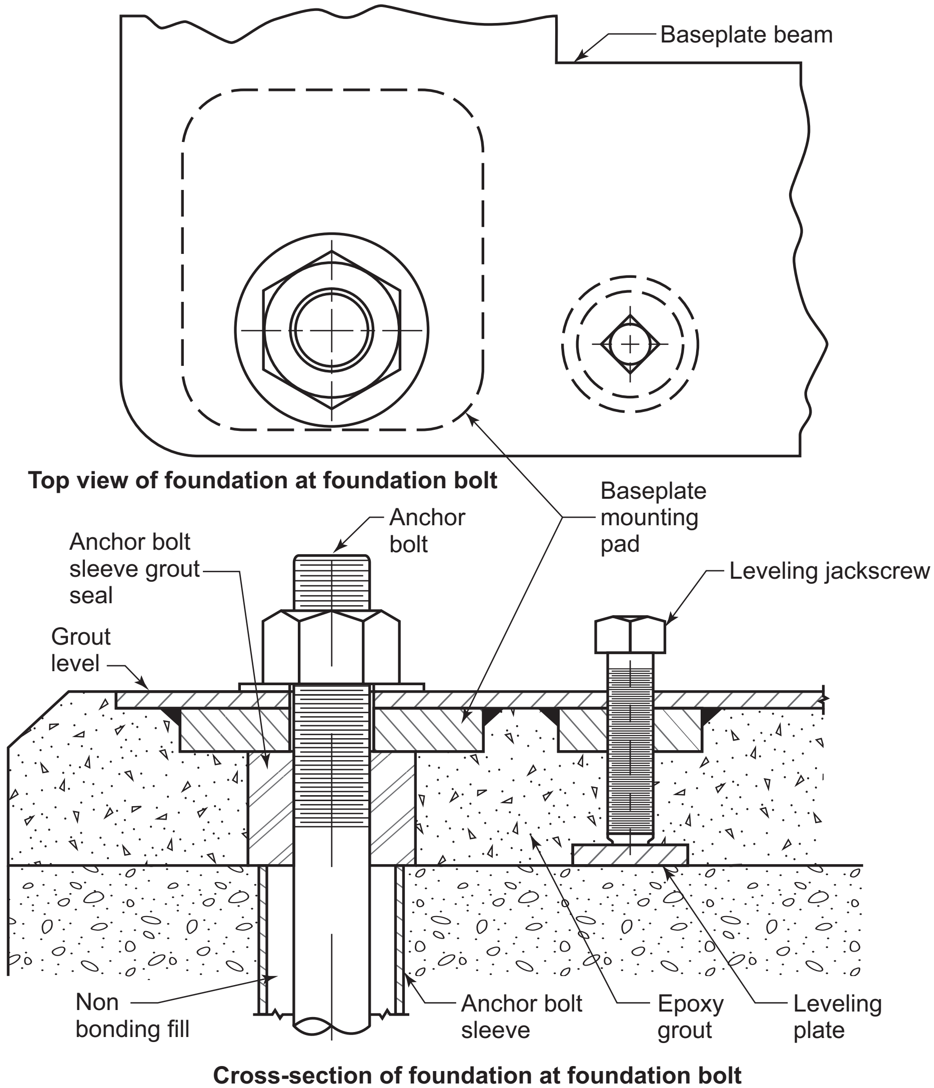


Figure 9—Typical Mounting Plate Arrangement 4

7.4.2.4 If a baseplate is provided, it shall extend under the drivetrain components so that any leakage from these components is contained within the baseplate.

● **7.4.2.5** If specified, the baseplate shall be suitable for column mounting (i.e. of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

7.4.2.6 The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting lugs attached to the equipment shall be designed using a maximum allowable stress of one-third of the specified minimum yield strength of the material. Welding applied to lifting lugs shall be full penetration, continuous welds and be in accordance with ANSI/AWS D1.1 (ISO 15614). The welds shall be 100 % NDE tested in accordance with the applicable code. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it.

7.4.2.7 The bottom of the baseplate between structural members shall be open. When the baseplate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 20 in.^{2} (125 cm^2) and no dimension less than 3 in. (75 mm) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members. Where practical, the holes shall be accessible for grouting with the equipment installed. The holes shall have $^1/_2$-in. (13-mm) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided. Vent holes at least $^1/_2$ in. (13 mm) in size shall be provided at the highest point in each bulkhead section of the baseplate.

7.4.2.8 The underside of mounting surfaces of the baseplate shall be in one plane to permit use of a single-level foundation. When multisection baseplates are provided, the mounting pads shall be in one plane after the baseplate sections are doweled and bolted together. For AMCA arrangement 3 fans, multiple level foundations are permitted.

7.4.2.9 Unless otherwise specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

NOTE Nonskid surfaces can be obtained by nonskid coatings or grating over the metal decking.

7.4.2.10 Support for the major components shall be located beneath the equipment feet and shall extend in line vertically to the bottom of the baseplate.

- **7.4.2.11** If specified, subsoleplates shall be provided by the vendor.

7.4.3 Soleplates and Subsoleplates

7.4.3.1 If soleplates have been specified, they shall meet the requirements of 7.4.3.2 and 7.4.3.3 in addition to those of 7.4.1.

NOTE Refer to Figure 7 and Figure 9 for typical sketches.

7.4.3.2 Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, but in no case shall the plates be less than 1 $^1/_2$ in. (40 mm) thick.

7.4.3.3 If subsoleplates have been specified, they shall be steel plates at least 1 in. (25 mm) thick. The finish of the subsoleplates' mating surfaces shall match that of the soleplates (see 7.4.1.3).

7.5 Controls and Instrumentation

7.5.1 General

- **7.5.1.1** Instrumentation and installation shall conform to the requirements of API 614 or purchaser's specifications, as specified.

- **7.5.1.2** Unless otherwise specified, controls and instrumentation, equipment and wiring shall be designed for outdoor installation. They shall have a minimum ingress protection level of IP 65 as detailed in IEC 60529 or a NEMA 4 minimum rating per NEMA 250, as specified. When IP 65 protection level is specified, the controls and instrumentation, equipment and wiring shall comply with the construction requirements of IEC 60079.

- **7.5.1.3** Terminal boxes shall have a minimum ingress protection level of IP 66 as detailed in IEC 60529 or a NEMA 4X minimum rating per NEMA 250, as specified. When IP 66 protection is specified, the terminal boxes shall comply with the construction requirements of IEC 60079. Terminal boxes shall be metal.

NOTE 1 IEC addresses environment protection and electrical protection separately. Ingress protection is covered by the IP designation in IEC 60529. Electrical protection is covered by IEC 60079.

NOTE 2 The *IP Code* only addresses requirements for protection of people, ingress of solid objects, and ingress of water. There are numerous other requirements covered by the NEMA type designations that are not addressed by the IEC 60529/*IP Codes*. IEC 60529 does not specify the following:

— construction requirements,

— door and cover securement,

— corrosion resistance,

— effects of icing,

— gasket aging and oil resistance,

— coolant effects.

The type designation of NEMA specifies requirements for these additional performance protections. For this reason, the IEC enclosure *IP Code* designations cannot be converted to enclosure NEMA type numbers. (NEMA Publication *A Brief Comparison of NEMA 250 and IEC 60529*.)

NOTE 3 NEMA addresses both environmental and electrical protection (construction features) in one standard, NEMA 250.

7.5.1.4 Instrumentation and controls shall be designed and manufactured for use in the area classification (class, group, and division or zone) specified in 6.1.12.

7.5.1.5 All conduit, armored cable, and supports shall be designed and installed so that it can be easily removed without damage and shall be located so that it does not hamper removal of bearings, seals, or equipment internals.

• **7.5.1.6** If specified, permanently mounting seismic vibration transducers shall be provided.

• **7.5.1.7** If specified, bearing metal temperature detectors shall be provided in accordance with API 670. Purchaser will specify type of temperature detector required.

• **7.5.1.8** If specified, a noncontacting speed measurement probe or a mechanical type speed activated switch shall be provided. If a mechanical type device is provided, it shall be supported from the fan bearing pedestal.

NOTE This speed sensor or switch may be used to monitor speed on variable speed drives, start the backup drive on dual-drive applications, or shut down on overspeed.

• **7.5.1.9** If specified, bearing oil temperature indicators shall be provided.

7.5.2 Additional Requirements for Special Purpose Fans

• **7.5.2.1** If specified, fans with hydrodynamic bearings shall be provided with two radial vibration (proximity) probes adjacent to each bearing and a one-event-per-revolution probe in each machine. The probe installation shall be as specified in API 670.

NOTE Proximity probes are not appropriate for use with antifriction bearings. If permanently installed vibration monitoring is required, seismic transducers per 7.5.1.6 should be specified.

7.5.3 Control Systems

• **7.5.3.1** The fan may be controlled on the basis of inlet pressure, discharge pressure, flow, or some combination of these parameters. This may be accomplished by suction throttling (by a damper or variable inlet guide vanes), speed variation, or discharge blowoff (when a constant speed drive is used). The control system may be mechanical, pneumatic, hydraulic, electrical, or any combination thereof. The system may be manual or it may be automatic with a manual override. The purchaser shall specify the source of the control signal, its sensitivity and range, and the equipment to be furnished by the vendor.

7.5.3.2 For constant speed drives, the control signal shall actuate an operator that positions an inlet and/or outlet damper or adjustable inlet guide vanes. (Also called radial inlet damper, variable inlet vanes, vortex dampers.)

7.5.3.3 For variable-speed drives, the control signal shall act to adjust the set point of the driver's speed-control system. The speed of the machine shall vary linearly and directly with the control signal. Unless otherwise specified, the control range shall be from the maximum continuous speed to 95 % of the minimum speed required for any specified operating condition or 70 % of maximum continuous speed, whichever is lower.

7.5.3.4 The full range of the specified control signal shall correspond to the required operating range of the driven equipment. Unless otherwise specified, the maximum control signal shall correspond to the maximum continuous speed or the maximum flow.

• **7.5.3.5** Facilities shall be provided to automatically open or close (as specified) the dampers/guide vanes on loss of control signal and to automatically lock or brake the dampers or vanes in last position on loss of motive force (air supply, electric power, etc.).

NOTE This is a specific system consideration and the associated controls should be arranged to avoid creating hazardous or other undesirable conditions.

7.5.3.6 The fan vendor shall furnish and locate the operators, actuator linkages, and operating shafts for remote control of the dampers/guide vanes. Operator output shall be adequate for the complete range of damper or guide vane positions. The proposed location of operators, linkages, and shafts shall be reviewed with the purchaser for consideration of maintenance access and safety.

7.5.3.7 External position indicators shall be provided for all dampers/inlet guide vanes.

7.5.4 Dampers or Inlet Guide Vanes

7.5.4.1 Frames for inlet dampers (unless integral with the inlet box) and outlet dampers shall be flanged and drilled air tight steel, using tight fitting bolting to connect the fan or duct work. Dampers shall be of either the parallel or opposed blade type, as appropriate to the specified control requirements. Damper blades shall be supported continuously by the shafts and not extend beyond the frame in the full open position. Stub shafts are not allowed. Damper shafts shall be sealed or packed to limit leakage (except for atmospheric air fan inlets).

• **7.5.4.2** If specified, the vendor shall state the maximum expected leakage through closed damper/vanes at purchaser's specified operating temperature and pressure. Leakage shall be stated with the fan operating.

7.5.4.3 The damper/vane mechanisms shall be interconnected to a single operator. The operating mechanism shall be designed so the dampers/vanes can be manually secured in any position.

7.5.4.4 Inlet variable guide vane operating mechanisms shall be located outside the flowing gas stream. The mechanism shall be readily accessible for in-place inspection and maintenance and be of bolted attachment construction to permit removal if necessary. Provision shall be furnished for lubrication of the mechanism during operation.

7.5.4.5 Inlet dampers/vanes shall be continuously welded to the spindle or intermittently welded on the backside of the blade with full slot welds along the full length of the front side.

7.5.5 Instrument and Control Panels

• **7.5.5.1** If specified, a panel shall be provided and shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The purchaser will specify whether the panel is to be freestanding, located on the base of the unit, or in another location, as specified. The instruments on the panel shall be clearly visible to the operator from the driver control point. If the panel contains lamps, a lamp test push button shall be provided. The instruments to be mounted on the panel will be specified.

• **7.5.5.2** Unless otherwise specified, panels shall be reinforced, self-supporting and closed on the top and sides. The front shall be steel plate at least $^1/_8$ in. (3 mm) thick. Top and sides shall be a minimum of 12 gauge in accordance with Table 7. If specified, panels shall be totally enclosed to minimize electrical hazards, to prevent tampering or to allow purging for safety or corrosion protection. All instruments shall be flush mounted on the front of the panel and fasteners shall be of corrosion resistant metal. All interior and exterior surfaces of carbon steel panels shall be suitably prepared and coated with an industrial grade coating system.

Table 7—Control Panel Plate Thickness

12 Gage Steel	**Material Thickness** in.
Uncoated	0.1046
Galvanized	0.0934
Stainless Steel	0.1094

7.5.5.3 Gauge boards and panels shall be completely assembled, piped, and wired, requiring only connection to the purchaser's external piping and wiring circuits.

7.5.5.4 If more than one wiring point is required on a unit for control or instrumentation, the wiring to each electrical control device or instrument shall be provided from terminal box(es) with terminal posts. Unless otherwise specified, separate terminal boxes shall be supplied for segregation of the AC and DC electrical signals. Each terminal box shall be mounted on the unit, baseplate or shipped loose as specified. With purchaser's approval one terminal box may be provided if it is provided with an interior barrier that separates the AC and DC wiring.

7.5.5.5 In addition to the requirements in 7.5.5.4, additional signal segregation by terminal boxes shall be specified.

7.5.5.6 Unless otherwise specified, each terminal box shall be mounted on the unit or baseplate.

NOTE Terminal boxes on some soleplate mounted equipment can result in maintenance access problems. Maintenance access problems can be addressed by shipping terminal boxes loose for field wiring to a nearby location.

• **7.5.5.7** All leads and posts on terminal strips, switches, and instruments shall be tagged for identification. If specified, purchasers tagging shall be supplied in addition to the vendors tagging. Wiring inside panels shall be neatly run in wire ducting.

7.5.5.8 Interconnecting piping, tubing, or wiring for controls and instrumentation, furnished by the vendor, shall be disassembled only to the extent necessary for shipment.

7.6 Piping

7.6.1 General

7.6.1.1 Piping design, joint fabrication, examination, and inspection shall be in accordance with ASME B31.3. Welding of shall be performed in accordance with 7.6.1.2.

7.6.1.2 Welding of piping and pressure containing parts of auxiliary equipment shall be performed and inspected by operators and procedures qualified in accordance with ASME *BPVC*, *Section VIII*, *Division 1* and ASME *BPVC*, *Section IX* or purchaser approved standard such as EN 287 and EN 288 for weld qualifications and procedures.

7.6.1.3 Auxiliary systems are piping systems that include following services.

a) Group I:

   1) sealing fluid,

   2) buffer gas,
   3) process-side drains and vents.

b) Group II:
   1) sealing steam,
   2) instruments and control air,
   3) drains and vents associated with above systems.

c) Group III:
   1) cooling water,
   2) liquid wash,
   3) drains and vents associated with above systems.

d) Group IV:
   1) lubricating oil,
   2) control oil,
   3) oil system drains and vents.

Auxiliary systems shall comply with the requirements of Table 8.

• **7.6.1.4** The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, any oil console base area, or any auxiliary base area. The piping shall terminate with flanged connections at the edge of the base. When soleplates are specified for the equipment train, the extent of the piping system at the equipment train shall be defined by the purchaser. The purchaser shall furnish only interconnecting piping between equipment groupings and off-base facilities.

7.6.1.5 The design of piping systems shall achieve the following:

a) proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance;

b) proper flexibility and adequate accessibility for operation, maintenance, and thorough cleaning;

c) installation in a neat and orderly arrangement adapted to the contours of the equipment without obstructing access areas;

d) elimination of air pockets by the use of valved vents or nonaccumulating piping arrangements;

e) complete drainage through low points without disassembly of piping.

7.6.1.6 Piping systems shall include piping, tubing where permitted, isolating valves, control valves, relief valves, pressure reducers, orifices, temperature gauges and thermowells, pressure gauges, sight flow indicators, and all related vents and drains.

Table 8—Minimum Requirements for Piping System Components

System	Steam		Cooling Water		Lube Oil	
	≤75 psig	>75 psig	Standard (≤NPS 1)	Optional	≤NPS 1	≥NPS 1 1/2
Pipe	Seamless [a]	Seamless [a]		ASTM A53, Type F Schedule 40, galvanized to ASTM A153		ASTM A312, Type 304 or 316 stainless steel [b]
Tubing	ASTM A269, seamless Type 304 or 316 stainless steel [c]		ASTM A269, seamless Type 304 or 316 stainless steel [c]		ASTM A269, seamless Type 304 or 316 stainless steel [c]	
All valves	Carbon steel, Class 800	Carbon steel, Class 800	Bronze, Class 200	Bronze, Class 200	Carbon steel, Class 800	Carbon steel, Class 800
Gate and globe valves	Bolted bonnet and gland	Bolted bonnet and gland			Bolted bonnet and gland	Bolted bonnet and gland
Pipe fittings and unions	Forged, Class 3000	Forged, Class 3000	ASTM A338 and ASTM A197, Class 150 malleable iron, galvanized to ASTM A153	ASTM A338 and ASTM A197, Class 150 malleable iron, galvanized to ASTM A153	Stainless steel	Stainless steel
Tube fittings	Carbon steel, compression, manufacturer's standard		Manufacturer's standard		Carbon steel, compression, manufacturer's standard	
Fabricated joints ≤1 1/2 in.	Threaded	Socket welded	Threaded	Threaded		Carbon steel slip-on flange
Fabricated joints ≥2 in.	Slip-on flange	Socket-weld or weld-neck flange	Purchaser shall specify	Purchaser shall specify		Carbon steel slip-on flange
Gaskets	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel				Type 304 or 316 stainless steel, spiral wound
Flange bolting	ASTM A193, Grade B7; ASTM A194, Grade 2H	ASTM A193, Grade B7; ASTM A194, Grade 2H				ASTM A193, Grade B7; ASTM A194, Grade 2H

NOTE Carbon steel piping shall conform to ASTM A106, Grade B; ASTM A524; or API 5L, Grade A or Grade B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A105 and ASTM A181. Stainless steel piping shall conform to ASTM A312.

[a] Schedule 80 for diameters from 1/2 in. to 1 1/2 in.; Schedule 40 for diameters 2 in. and larger.

[b] Schedule 40 for a diameter of 1 1/2 in.; Schedule 10 for diameters of 2 in. and larger.

[c] 1/2-in. diameter × 0.065-in. wall, 3/4-in. diameter × 0.095-in. wall, or 1-in. diameter × 0.109-in. wall.

7.6.1.7 Piping shall preferably be fabricated by bending and welding to minimize the use of flanges and fittings. Flanges are permitted only at equipment connections, at the edge of any base, and for ease of maintenance. The use of flanges at other points is permitted only with the purchaser's specific approval. Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas. Threaded connections shall not be used except (with the purchaser's approval) where essential for space or access reasons. Pipe bushings shall not be used.

• **7.6.1.8** Pipe threads, where permitted, shall be taper threads in accordance with ASME B1.20.1 or ISO 7-1 as specified. If ISO 7, Part 1 has been specified, tapered or straight internal threads shall also be specified. Flanges shall be steel and in accordance with 6.3.2.12.

7.6.1.9 Connections, piping, valves, and fittings that are 1 $^{1}/_{4}$ in. (32 mm), 2 $^{1}/_{2}$ in. (65 mm), 3 $^{1}/_{2}$ in. (90 mm), 5 in. (125 mm), 7 in. (175 mm), or 9 in. (225 mm) in size shall not be used.

7.6.1.10 Where space does not permit the use of NPS $^{1}/_{2}$, $^{3}/_{4}$, or 1 pipe, seamless tubing may be furnished in accordance with Table 8.

7.6.1.11 The minimum size of any connection shall be NPS $^{1}/_{2}$.

7.6.1.12 Piping systems furnished by the vendor shall be fabricated, installed in the shop, and properly supported. Bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centerline of the equipment.

7.6.1.13 Pipe plugs shall be in accordance with 6.3.2.10.

7.6.2 Oil Piping

7.6.2.1 Gravity return lines shall be sized to run no more than half full when flowing at a velocity of 1 ft/s (0.3 m/s) and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Gravity return lines shall have a downward slope towards the reservoir of not less than 4 %. If possible, lateral branches (not more than one in any transverse plane) should enter drain headers at approximately 45° angles in the direction of flow.

7.6.2.2 Nonconsumable backup rings and sleeve-type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions that could accumulate dirt. Socket-welded fittings shall not be used in pressure piping downstream of oil filters. (See Table 8.)

7.6.2.3 Unless otherwise specified, oil supply piping and tubing, including fittings (excluding slip-on flanges), shall be stainless steel. (See Table 8.)

7.6.2.4 Provision shall be made for bypassing the bearings (and seals if applicable) of equipment during oil system flushing operations.

7.6.3 Instrument Piping

7.6.3.1 The vendor shall supply all necessary piping, valves, and fittings for instruments and control panels.

7.6.3.2 Initial connections for pressure instruments and test points shall comprise a branch and isolation valve to the same standard as the system to which it is connected. Beyond the initial isolation valve, piping or tubing not less than 0.375 in. (10 mm) outside diameter may be used. Where convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Such common connections shall not be smaller than NPS $^{1}/_{2}$ (DN 15), and separate secondary isolation valves shall be provided for each instrument. Where a pressure gauge is to be used for testing pressure alarm or shutdown switches, common connections are required for the pressure gauge and the associated switches.

7.6.4 Process Piping

• **7.6.4.1** The extent of and requirements for process piping or ducting to be supplied by the vendor will be specified.

7.6.4.2 The requirements of 7.6.1 shall apply to process piping supplied by the vendor.

NOTE Requirements for ducting are special and shall be as agreed between vendor and purchaser.

• 7.7 Inlet Trash Screens

7.7.1 If specified, the vendor shall furnish inlet trash screen(s) for forced draft fans to prevent entry of debris. The screen shall be fabricated from 0.135 in. (3.5 mm) minimum diameter wire, with a mesh of 1/2 in. (15 mm) maximum opening. The screen shall be supported by cross members. All construction material shall be galvanized steel or other corrosion resistant metal as specified by the purchaser. If specified, the vendor shall furnish rain hood(s). Rain hood material shall be specified by the purchaser.

NOTE Compliance with the inlet trash screen portion of this paragraph will satisfy the requirement for inlet ingress protection for open inlet fans in 6.3.1.2.

7.8 Silencers

• **7.8.1** If specified, fan inlet or exhaust silencers shall be provided and include the features in 7.8.2. The differential pressure through each silencer shall not exceed 1 in. (25.4 mm) water at rated conditions.

7.8.2 Full details of the proposed silencer(s) shall be submitted with the proposal for purchaser's approval. Silencers shall be designed to prevent damage to any components resulting from acoustic or mechanical resonances. Carbon steel construction shall be 3/16 in. (5 mm) minimum thickness plate. Corrosion allowance or alternative materials may be specified by the purchaser. Main connections shall be flanged.

7.9 Insulation and Jacketing

• **7.9.1** If specified, the vendor shall weld clips or studs on the outside surface of fan housings and their inlet box(es) and discharge connections to permit field installation of insulation by the purchaser (for thermal conservation, noise abatement, personnel protection, or to maintain the enclosure temperature above the gas dew point). The clips or studs shall allow for the installation of insulation having a thickness of 2 in. (50 mm) or greater.

7.9.2 The vendor shall include in the proposal the recommended insulation material and thickness where the above specified minimum is not sufficient for personnel protection/sound attenuation.

• **7.9.3** The insulation/jacketing shall extend over all portions of the fan housing, inlet box(es), and discharge connections that may reach normal operating temperature of 165 °F (75 °C) or higher. Insulation shall not interfere with damper/vanes or other operating mechanisms. If specified, this material will be provided by the fan vendor.

7.9.4 Insulation/jackets shall maintain a surface temperature of 165 °F (75 °C) or less under normal operation. They shall be designed to minimize damage during removal or replacement.

7.10 Turning Gears

• **7.10.1** If specified, or recommended by the vendor, a turning gear shall be provided.

7.10.2 The device shall be manually or automatically engaged and shall automatically disengage when the fan is placed into service.

• **7.10.3** The turning gear will be driven as specified (steam, hydraulic, electric, or pneumatic). Provision to start from rest will be agreed between purchaser and vendor.

7.11 Special Tools

7.11.1 If special tools or fixtures are required to disassemble, assemble or maintain the equipment, they shall be included in the quotation and furnished as part of the initial supply of the equipment. For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be agreed between purchaser and vendor. These special tools shall be used, and their use demonstrated, during shop assembly and post-test disassembly of the equipment.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

8.1.1 After advance notification to the vendor, the purchaser's representative shall have entry to all vendor and subvendor plants where manufacturing, testing, or inspection of the equipment is in progress.

8.1.2 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test.

• **8.1.3** The purchaser shall specify the amount of advanced notification required for a witnessed or observed inspection or test.

8.1.4 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

• **8.1.5** The purchaser shall specify the extent of participation in the inspection and testing.

8.1.6 When shop inspection and testing have been specified, the purchaser and the vendor shall coordinate manufacturing hold points and inspectors' visits.

8.1.7 Equipment, materials and utilities for the specified inspections and tests shall be provided by the vendor.

8.1.8 The purchaser's representative shall have access to the vendor's quality program for review.

8.2 Inspection

8.2.1 General

8.2.1.1 The vendor shall keep the following data available for at least 20 years:

a) necessary or specified certification of materials, such as mill test reports;

b) test data and results to verify that the requirements of the specification have been met;

c) fully identified records of all heat treatment whether performed in the normal course of manufacture or as part of a repair procedure;

d) results of quality control tests and inspections;

e) details of all repairs;

f) final assembly maintenance and running clearances;

g) other data specified by the purchaser or required by applicable codes and regulations (see 2.1 and 9.3.1.1).

8.2.1.2 Pressure-containing parts shall not be painted until the specified inspection of the parts is complete.

• **8.2.1.3** In addition to the requirements of 6.10.1 and the ASTM material specifications, the purchaser shall identify:

a) parts that are to be subjected to surface and subsurface examination.

b) the type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic examination.

NOTE 1 Inspection of pressure containing components is covered in 6.10.1.

NOTE 2 ASTM material specifications contain mandated and supplemental inspections.

NOTE 3 Review of quality assurance and testing are items on the coordination meeting agenda in 9.1.3.

8.2.2 Material Inspection

8.2.2.1 General

8.2.2.1.1 When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the recommended practices in 8.2.2.2 through 8.2.2.5 shall apply unless other corresponding procedures and acceptance criteria have been specified. Cast iron may be inspected only in accordance with 8.2.2.2 and/or 8.2.2.5. Welds, cast steel, and wrought material shall be inspected in accordance with 8.2.2.2 through 8.2.2.5.1.

8.2.2.1.2 Acceptance standards for 8.2.2.2 through 8.2.2.5 shall be mutually agreed upon between the purchaser and vendor.

NOTE The user may wish to consult and use as a guide API 687, Ch. 1, Section 3, Table 1.8-1.

8.2.2.2 Radiography

8.2.2.2.1 Radiography shall be in accordance with ASTM E94.

8.2.2.3 Ultrasonic Inspection

8.2.2.3.1 Ultrasonic inspection shall be based upon the procedures ASTM A609 (castings), ASTM A388 (forgings), or ASTM A578 (plate).

8.2.2.4 Magnetic Particle Inspection

8.2.2.4.1 Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709.

8.2.2.5 Liquid Penetrant Inspection

8.2.2.5.1 Liquid penetrant inspection shall be based upon the procedures of ASTM E165.

8.2.3 Mechanical Inspection

• **8.2.3.1** Centrifugal fans shall be shop assembled prior to shipment. If specified, drivers (if provided) and other auxiliaries shall be included in the shop assembly. If disassembly is required for shipment, all mating parts shall be suitably match-marked and tagged for field assembly. All equipment shall be furnished completely assembled to the maximum extent possible limited only by the requirements of shipping.

8.2.3.2 During assembly of the equipment, each component (including integrally cast-in passages) and all piping and appurtenances shall be inspected to ensure they have been cleaned and are free of foreign materials, corrosion products, and mill scale.

8.2.3.3 All oil system components furnished shall meet the cleanliness requirements of API 614.

• **8.2.3.4** If specified, the purchaser shall inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the vendor before final assembly.

• **8.2.3.5** If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

8.3 Testing

8.3.1 General

8.3.1.1 Equipment shall be tested in accordance with 8.3.2 and 8.3.3. Other tests that may be specified by the purchaser are described in 8.3.4.

8.3.1.2 At least 6 weeks before the first scheduled running test, the vendor shall submit to the purchaser, for his/her review and comment, detailed procedures for the mechanical running test and all specified running optional tests (8.3.4) including acceptance criteria for all monitored parameters.

8.3.1.3 Notification requirements are covered in 8.1.3; however, running test requirements shall not be less than 5 working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than 5 working days before the new test date.

8.3.1.4 Acceptance of shop tests does not constitute a waiver of requirements to meet field performance under specified operating conditions, nor does inspection relieve the vendor’s responsibilities.

8.3.2 Hydrostatic Test

8.3.2.1 Pressure-containing parts other than fan housing, but including auxiliaries, shall be tested hydrostatically with liquid at a minimum of 1 $^1/_2$ times the MAWP but not less than gauge pressure of 20 psig (1.5 bar). The test liquid shall be at a higher temperature than the nil ductility transition temperature of the material being tested. (Reference ASTM E1003.)

NOTE The nil ductility temperature is the highest temperature at which a material experiences complete brittle fracture without appreciable plastic deformation.

8.3.2.2 Where applicable, tests shall be in accordance with the ASME *Code*. In the event that a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

8.3.2.3 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

NOTE Chloride content is limited in order to prevent stress corrosion cracking.

8.3.2.4 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum of 30 minutes. Large, heavy castings may require a longer testing period to be agreed upon by the purchaser and the vendor.

8.3.3 Mechanical Running Tests

• **8.3.3.1** If specified, a mechanical running test shall be performed.

NOTE Some fan manufacturers do not have the capability to perform shop mechanical run tests except on the smaller units.

8.3.3.2 The requirements of 8.3.3.2.1 through 8.3.3.2.7 shall be met before the mechanical running test is performed.

8.3.3.2.1 All warning, protective, and control devices used during the test shall be checked and adjusted as required.

8.3.3.2.2 Bearings intended to be lubricated by an oil mist systems shall be prelubricated.

8.3.3.2.3 All oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested. For pressure lubrication systems, oil flow rates for each bearing housing shall be measured.

8.3.3.2.4 The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

8.3.3.2.5 All purchased vibration probes, cables, oscillator-demodulators, and accelerometers shall be in use during the test. If vibration probes are not furnished by the equipment vendor or if the purchased probes are not compatible with shop readout facilities, then shop probes and readouts that meet the accuracy requirements of API 670 shall be used.

8.3.3.2.6 Shop test facilities shall include instrumentation with the capability of continuously monitoring, displaying, recording, and printing revolutions per minute, vibration, and phase angle (x-y-y). Presentation of vibration displacement and phase marker shall also be by oscilloscope.

8.3.3.2.7 The vibration characteristics determined by the use of the instrumentation specified in 8.3.3.2.5 and 8.3.3.2.6 shall serve as the basis for acceptance or rejection of the machine (6.7.5.2.5).

8.3.3.3 Mechanical tests shall include the following.

8.3.3.3.1 The fan shall be operated from 0 to 115 % of rated speed in approximately 10 % increments for VARIABLE SPEED drives and at 100 % of rated speed for CONSTANT SPEED drives. Operation shall be at maximum continuous speed for an uninterrupted period of at least two hours, after all measurements have stabilized, to check bearing performance and vibration

• **8.3.3.3.2** The fan rotor is to be operated at 110 % of the maximum allowable speed for up to one minute.

8.3.3.3.3 During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 6.7.4.4 and shall be recorded throughout the operating speed range.

8.3.3.3.4 All oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested. For pressure lubrication systems, oil flow rates for each bearing housing shall be measured.

8.3.3.3.5 The vibration characteristics determined by the use of the instrumentation specified in 8.3.3.2.5 and 8.3.3.2.6 shall serve as the basis for acceptance or rejection of the machine.

8.3.3.4 Hydrodynamic bearings shall be removed, inspected and reassembled after the mechanical running test is completed.

8.3.3.4.1 If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable and the final shop tests shall be run after these deficiencies are corrected.

8.3.4 Optional Tests

• 8.3.4.1 Performance Test

• **8.3.4.1.1** If specified, a performance test shall be run. The details and extent of the shop or field test shall be developed jointly by the purchaser and the vendor.

NOTE Typical testing procedures are contained in AMCA 210-99 and AMCA 802-02 for shop testing and AMCA 203-90 and AMCA 803-96 for field testing.

8.3.4.1.2 The fan performance shall meet all operating conditions specified on the datasheet and shall be within the tolerances listed in Items 1) and 2) at the rated operating conditions.

1) For variable-speed fans, the static pressure and capacity shall be met at fan rated point and the horsepower at this point shall not exceed 104 % of the specified value. Where changes in speeds are needed to meet static pressure rise requirements, the vendor shall adjust operating range.

2) For constant-speed fans, the specified capacity shall be met with the understanding that the static pressure rise shall be within +5 % and –0 % of that specified; the horsepower shall not exceed 104 % of the specified value.

8.3.5 Additional Requirements for Special Purpose Fans

8.3.5.1 Mechanical Running Tests

8.3.5.1.1 The mechanical run test is the same as for general purpose fans, except the test is required and the time is increased from two hours to four hours.

8.3.6 Complete Unit Test

• If specified, such components as fans, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. If specified, torsional vibration measurements shall be made to verify the vendor's analysis. The complete-unit test may be performed in place of or in addition to separate tests of individual components specified.

8.3.7 Pressure Test

• **8.3.7.1** If specified, the casing (with or without end seals installed) shall be pressurized with air to the MAWP and held at this pressure for a minimum of 30 minutes and subjected to a soap bubble test or another approved test to check for gas leaks. The test shall be considered satisfactory when no casing or casing joint leaks are observed.

• 8.3.8 Sound-level Test

• **8.3.8.1** If specified a sound-level test shall be performed in accordance with ISO 3744 or other agreed standard.

• 8.3.9 Resonance Test

• **8.3.9.1** If specified, the fan rotor component parts are to be excited by impact or other appropriate means and the vibration spectrum measured. No excitable resonances are acceptable within 10 % of the fan operating speed or blade passage frequency.

• 8.3.10 Auxiliary Equipment Test

• **8.3.10.1** If specified, auxiliary equipment such as oil systems, gears, and control systems shall be tested in the vendor's shop. Details of the auxiliary equipment tests shall be developed jointly by the purchaser and the vendor.

8.4 Preparation for Shipment

8.4.1 Equipment shall be prepared for the type of shipment specified, including blocking of the rotor when necessary. Blocked rotors shall be identified by means of corrosion-resistant tags attached with stainless steel wire. The preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

8.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and prior to start-up, as described in API 686, Ch. 3, *Recommended Practices for Machinery Installation and Installation Design.*

8.4.3 Except for machined surfaces, all exterior surfaces that may corrode during shipment, storage, or in service shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates. Stainless steel parts need not be painted. The underside of the baseplates shall be prepared for grout in accordance with 7.4.1.7.

8.4.4 Exterior machined surfaces except for corrosive resistant material shall be coated with a suitable rust preventive.

8.4.5 The interior of the equipment shall be clean; free from scale, welding spatter, and foreign objects; and sprayed or flushed with a rust preventive that can be removed with solvent. The rust preventive shall be applied through all openings while the rotor is rotated.

8.4.6 Internal surfaces of bearing housings and carbon steel oil systems' components shall be coated with an oil-soluble rust preventive that is compatible with the lubricating oil.

8.4.7 Flanged openings shall be provided with metal closures at least $^{3}/_{16}$ in. (5 mm) thick with elastomeric gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures. Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.

8.4.8 Flanged openings for auxiliary piping connections shall be provided with metal closures at least $^{3}/_{16}$ in. (5 mm) thick, with elastomeric gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures. Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.

8.4.9 Threaded openings shall be provided with steel caps or round head steel plugs. In no case shall nonmetallic (such as plastic) plugs or caps be used.

NOTE These are shipping plugs. Permanent plugs are covered in 6.3.2.10.

8.4.10 Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be as described in 9.3.5.2 in the installation manual.

8.4.11 The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. Crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

• **8.4.12** A spare rotor, when purchased, shall be prepared for unheated indoor storage for a period of at least 3 years. It shall be treated with a rust preventive and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor. The rotor shall be crated for domestic or export shipment as specified. A purchaser-approved resilient material $^{1}/_{8}$ in. (3 mm) thick [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)] shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported on journals. Mark the probe target area barriers with the words "Probe Area—Do Not Cut." If specified, the rotor shall be prepared for vertical storage. It shall be supported from its coupling end with a fixture designed to support 1.5 times the rotor's weight without damaging the shaft. Instructions on the use of the fixture shall be included in the installation, operation, and maintenance manuals.

NOTE TFE and PTFE are not recommended as cradle support liners since they cold flow and impregnate into the surface.

8.4.13 Critical shaft areas such as journals, end seal areas, probe target areas, and coupling fit areas shall be protected with a corrosion barrier followed by a separate barrier material to protect against incidental mechanical damage.

8.4.14 Loose components shall be dipped in wax or placed in plastic bags and contained by cardboard boxes. Loose boxes are to be securely blocked in the shipping container.

8.4.15 Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

8.4.16 Bearing assemblies shall be fully protected from the entry of moisture and dirt. If vapor-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags shall be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers and bag locations shall be indicated by corrosion-resistant tages attached with stainless steel wire.

8.4.17 One copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment

8.4.18 Connections on auxiliary piping, removed for shipment, shall be match marked for ease of reassembly.

8.4.19 Fans that have to be disassembled for shipment shall be reassembled with ALL components (bolting and plates, etc.) that are to be utilized for final installation.

9 Vendor Data

9.1 General

• **9.1.1** The information to be furnished by the vendor is specified in 9.2 and 9.3. Purchaser shall complete Vendor Drawing and Data Requirements Form (see Annex G) clearly showing all information and drawings required for both proposals and contract data. Purchaser shall include any optional requirements that may be specific to this equipment. The vendor shall complete and forward the Vendor Drawing and Data Requirements Form (see Annex G) with his/her proposal. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

9.1.2 The data shall be identified on transmittal (cover) letters, title pages, and in title blocks or other prominent position on drawings, with the following information (9.2.1, 9.3.1.1, 9.3.4.1, and 9.3.5.1):

a) the purchaser/user's corporate name;

b) the job/project number;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

e) any other identification specified in the inquiry or purchase order;

f) the vendor's identifying proposal number, shop order number, serial number, or other reference required to completely identify return correspondence.

• **9.1.3** If specified, a coordination meeting shall be held, preferably at the vendor's plant, within 4 to 6 weeks after order commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting, which as a minimum shall include review of the following items:

a) the purchase order, scope of supply, unit responsibility, subvendor items, and lines of communication;

b) the datasheets;

c) applicable specifications and previously agreed upon exceptions;

d) schedules for transmittal of data, production, and testing;

e) the quality assurance program and procedures;

f) inspection, expediting, and testing;

g) schematics and bills of material for auxiliary systems;

h) the physical orientation of the equipment, piping, and auxiliary systems, including access for operation and maintenance;

i) coupling selection and rating;

j) thrust and journal bearing sizing, estimated loadings, and specific configurations;

k) the rotor dynamics analysis, if specified;

l) equipment performance, alternate operating conditions, start-up, shutdown, and any operating limitations;

m) instrumentation and controls;

n) identification of required design reviews;

o) inspection, related acceptance criteria ,and testing;

p) expediting;

q) other technical items.

9.2 Proposals

9.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 9.2.2 through 9.2.4, as well as a specific statement that the system and all its components are in strict accordance with this standard. If the equipment or any of its components or auxiliaries are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 9.1.2.

9.2.2 Drawings

9.2.2.1 The drawings indicated on the Vendor Drawing and Data Requirements Form (see Annex G) shall be included in the proposal. As a minimum, the following data shall be furnished.

a) A general arrangement or outline drawing for each machine train or skid mounted package, showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights, and maximum maintenance weight for each item. The direction of rotation and the size and location of major purchaser connections shall also be indicated.

b) Cross-sectional drawings showing the details of the proposed equipment.

c) Schematics of all auxiliary systems, including lube oil, control, and electrical systems. Bills of material shall be included.

d) Sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries. [This information may be included on the drawings specified in Item a) above.]

9.2.2.2 If typical drawings, schematics, and bills of material are used, they shall be marked up to show the weight and dimension data for the actual equipment and scope included in the proposal.

9.2.3 Technical Data

The following data shall be included in the proposal.

a) The purchaser's datasheets, with complete vendor's information entered thereon and literature to fully describe details of the offering.

b) The purchaser's noise datasheet.

c) The Vendor Drawing and Data Requirements Form (see Annex G), indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.

d) A schedule for shipment of the equipment, in weeks after receipt of the order.

e) A list of major wearing components, showing interchangeability with the owner's existing machines.

f) A list of spare parts recommended for start-up and normal maintenance purposes.

g) A list of the special tools furnished for maintenance. The vendor shall identify any metric items included in the offering.

h) A description of any special weather protection and winterization required for start-up, operation, and periods of idleness under the site conditions specified on the datasheets. The description shall clearly indicate the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply.

i) A complete tabulation of utility requirements, such as those for steam, water, electricity, air, gas, and lube oil (including the quantity of lube oil required and the supply pressure, and the heat load to be removed by the oil), and the nameplate power rating and operating power requirements of auxiliary drivers. (Approximate data shall be defined and clearly identified as such.)

j) A description of any optional or additional tests and inspection procedures for materials, as required by 6.10.1.3.

k) A description of any special requirements specified in the purchaser's inquiry or as outlined in 6.9.2.3, 6.8.5.10, 6.10.1.2, and 6.10.1.5.

l) A list of similar machines installed and operating under conditions analogous to those specified in the proposal.

m) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.

n) For constant speed units, the vendor shall outline the procedure that can be followed to reduce power consumption, in the event that excess pressure or flow is developed.

o) A list of any components that can be construed as being of alternative design, hence requiring purchaser's acceptance.

p) The vendor shall identify any component or maintenance requirement that would result in the need to shut down the equipment within the uninterrupted operational period (6.1.1).

9.2.4 Curves

9.2.4.1 The vendor shall provide complete performance curves to encompass the map of operation, with any limitations indicated thereon. Any special inlet or outlet duct design required to meet performance shall be fully described.

9.2.4.2 The vendor shall provide sufficient fan performance data to enable the purchaser to properly design a control system for start-up and for all specified operating conditions. When requested by the purchaser, the vendor shall review the purchaser's overall fan control system for compatibility with vendor-furnished control equipment.

9.2.5 Optional Tests

The vendor shall furnish an outline of the procedures to be used for each of the special or optional tests that have been specified by the purchaser or proposed by the vendor.

9.3 Contract Data

9.3.1 General

9.3.1.1 The contract data to be furnished by the vendor is specified in Annex G.

9.3.1.2 Each drawing, bill of material, and datasheet shall have a title block in its lower right-hand corner that shows the date of certification, identification data specified in 9.1.2, the revision number and date, and the title.

9.3.1.3 The purchaser shall promptly review the vendor's data upon receipt; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data has been reviewed and accepted, the vendor shall furnish certified copies in the quantity specified.

9.3.1.4 A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of all the data (see Annex G).

9.3.2 Drawings and Technical Data

9.3.2.1 The drawings and data furnished by the vendor shall contain sufficient information so that with the drawings and the manuals specified in 9.3.5, the purchaser can properly install, operate, and maintain the equipment covered by the purchase order. All contract drawings and data shall be clearly legible, shall be identified in accordance with 9.3.1.1, shall cover the scope of the agreed upon Vendor Drawing and Data Requirements Form, and shall satisfy the applicable detailed descriptions in Annex G. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notations will result in the purchaser's issue of completed, corrected datasheets as part of the order specifications.

9.3.3 Progress Reports

The vendor shall submit progress reports to the purchaser at the intervals specified on the Vendor Drawing and Data Requirements Form (see Annex G).

9.3.4 Parts Lists and Recommended Spares

9.3.4.1 The vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include part names, manufacturer's unique part numbers, materials of construction identified as specified in 6.10.1.2, and delivery times. Each part shall be completely identified and shown on cross-sectional, assembly-type cutaway drawings or exploded view isometric drawings. Interchangeable parts shall be identified as such. Parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number. Standard purchased items shall be identified by the original manufacturer's name and part number.

9.3.4.2 The vendor shall indicate on the above parts lists all parts that are recommended spares for start-up and which parts are recommended for normal maintenance [see 9.2.3 f)] and the recommended stocking quantities These should include subvendor spare parts recommendations that were not available for inclusion in the vendor's original proposal. The vendor shall forward the lists to the purchaser promptly after receipt of the approved drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified in 9.1.2.

9.3.5 Installation, Operation, Maintenance, and Technical Data Manuals

9.3.5.1 General

The vendor shall provide sufficient written instructions and a list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information specified in 9.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual pages and drawings shall be numbered. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order; a typical manual is not acceptable.

9.3.5.2 Installation Manual

All information required for the proper installation of the equipment shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded when it is mutually agreed upon in the order but not later than the final issue of certified drawings. The manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centers of mass, rigging provisions and procedures, and all other installation data, including the drawings and data specified in 9.2.2 and 9.2.3 that are pertinent to proper installation. One extra manual, over and above the specified quantity, shall be included with the first equipment specified.

9.3.5.3 Operating and Maintenance Manual

The manual containing all required operating and maintenance instructions shall be supplied at shipment. In addition to covering operation at all specified process conditions, this manual shall include a section that provides special instructions for operation at specified extreme environmental conditions. As a minimum, the manual shall also include all of the data listed in Annex G.

• 9.3.5.4 Technical Data Manual

If specified, the vendor shall provide the purchaser with a technical data manual at shipment (see Annex G for detailed requirements).

Annex A
(informative)

Centrifugal Fan Datasheets

JOB NO. ____ ITEM NO. ____
PURCHASE ORDER NO. ____
SPECIFICATION NO. ____
REVISION NO. ____ DATE ____
PAGE ____ OF ____ BY ____

CENTRIFUGAL FAN (API 673, THIRD EDITION) DATASHEET U.S. CUSTOMARY UNITS

APPLICABLE TO: **PROPOSAL** UNITS OF MEASURE: **CUSTOMARY** REVISION: ____
FOR: ____
SITE: ____ UNIT: ____
SERVICE: ____ NO. REQUIRED: ____
NOTE: ○ INDICATES INFORMATION TO BE COMPLETED BY PURCHASER □ BY MANUFACTURER

GENERAL

FAN MFR. ____ SIZE ____ TYPE/ARRANGEMENT ____ SERIAL NO. ____
DRIVER MFR. ____ DRIVER TYPE ____ RATED HP ____ RPM ____
FURNISHED BY ____ MOUNTED BY ____ PER SPECIFICATION ____ PER DATASHEET ____
DRIVE SYSTEM ____ FAN ROTATION, FROM DRIVEN END ____
DUTY ○ GENERAL PURPOSE ○ SPECIAL PURPOSE

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)	NORMAL	RATED	OTHER CONDITIONS A	B	C	D
○ OPERATING CONDITION / CASE						
○ GAS HANDLED (See Page ____)						
○ DENSITY (lbm/ft³)						
○ DELIVERED SFCM						
○ WEIGHT FLOW lb/h (WET)						
INLET CONDITIONS:						
○ TEMPERATURE °F						
○ RELATIVE HUMIDITY (%)						
○ MOLECULAR WEIGHT (MIN.)						
□ INLET VOLUME (CFM WET)						
□ Cp / Cv (K_1) OR (K_{avg})						
□ COMPRESSIBILITY (Z_1) OR (Z_{avg})						
○ STATIC PRESSURE @ SOUND TRUCK (in WG)						
□ PRESSURE LOSS ACROSS SOUND TRUCK (in WG)						
○ STATIC PRESSURE @ INLET DAMPERS (in WG)						
○ STATIC PRESSURE @ FAN INLET (in WG)						
DISCHARGE CONDITIONS:						
□ STATIC PRESSURE @ FAN OUTLET (in WG)						
□ STATIC PRESSURE @ DISCHARGE DAMPER (in WG)						
□ rP ACROSS DISCHARGE DAMPER (in WG)						
□ rP ACROSS EVASE (in WG)						
○ STATIC PRESSURE @ EVASE OUTLET (in WG)						
PERFORMANCE:						
□ POWER REQUIRED @ TEMP. (ALL LOSSES INCL.) (HP)						
□ FAN SPEED (RPM)						
○ GUARANTEE POINT						
□ PERFORMANCE CURVE NO.						
□ STATIC rP ACROSS FAN (in WG)						
□ INLET DAMPER / VANE POSITION						
□ DISCHARGE DAMPER POSITION						
□ FAN STATIC EFFICIENCY (%)						

FAN CONTROL:
○ AIR SUPPLY ____ ○ FAN CONTROL FURNISHED BY ____
○ CONTROL SIGNAL TYPE ____ SOURCE ____ SENSITIVITY ____ RANGE ____
○ ARRANGEMENT DRAWING NO. ____ CONTROLSIGNAL FAILURE MODE ____ ○ CLOSE ○ OPEN ○ AUTOLOCK
METHOD: INLET DAMPER ____ OUTLET DAMPER ____ INLET GUIDE VANES ____
○ STARTING CONDITIONS ____ ○ STARTING METHOD ____
○ START & STOP RESTRICTIONS ____
○ VENDOR REVIEW OF CONTROL SYSTEM REQUIRED ○ OTHER ____

JOB NO. ____ ITEM NO. ____
REVISION NO. ____ DATE ____
PAGE ____ OF ____ BY ____

CENTRIFUGAL FAN (API 673, THIRD EDITION) DATASHEET U.S. CUSTOMARY UNITS

OPERATING CONDITIONS

GAS ANALYSIS ◯ MOL % ◯ ____	MW	NORMAL	RATED	CONDITIONS A	B	C	D	REMARKS
AIR	28.97							
OXYGEN	32.00							
NITROGEN	28.02							
WATER VAPOR	18.02							
CARBON MONOXIDE	28.01							
CARBON DIOXIDE	44.01							
HYDROGEN SULFIDE	34.08							
HYDROGEN CHLORIDE	36.47							
CHLORINE	70.91							
TOTAL								
AVG. MOL WT.								

CORROSIVES:
◯ CORROSION / EROSION CAUSED BY ____
◯ CORROSION / EROSION PROTECTION ____
◯ NACE MR-01-90 MATERIALS REQUIRED ____

LOCATION, SITE DATA

LOCATION:

SITE DATA:
◯ ELEVATION ____ ft ◯ BAR ____ psia
◯ TEMPERATURE ____ °F SUMMER ____ °F WINTER
◯ WIND LOAD ____ lbf/ft² ◯ VELOCITY ____ mph
◯ MINIMUM DESIGN METAL TEMPERATURE ____ °F

UNUSUAL CONDITIONS:

ELECTRICAL AREA CLASSIFICATION:
DIVISION SAFE

SPECIFICATIONS

NOISE SPECIFICATION:
◯ APPLICABLE TO MACHINE:
See Specification ____
◯ APPLICABLE TO NEIGHBORHOOD:
See Specification ____
ACOUSTIC HOUSING:

APPLICABLE SPECIFICATIONS:

PAINTING:

SHIPMENT:

ERECTION:
SHIPPED

☐ EXTENT OF FIELD ERECTION & ASSEMBLY ____
____ MAN HOURS ____
☐ OTHER ____

REMARKS: ____

CENTRIFUGAL FAN (API 673, THIRD EDITION) DATASHEET U.S. CUSTOMARY UNITS

JOB NO. ____ ITEM NO. ____
REVISION NO. ____ DATE ____
PAGE ____ OF ____ BY ____

CONSTRUCTION FEATURES

☐ **SPEEDS:**
MAX. CONT. ____ RPM TRIP ____ RPM
MAX. TIP SPEEDS ____ ft/s @ RATED
____ ft/s @ MAX. CONT.
☐ **LATERAL CRITICAL SPEEDS (6.7.2):**
FIRST CRITICAL ____ RPM ____
◯ TRAIN LATERAL ANALYSIS REQUIRED
◯ SUBMIT X-Y PLOT (COUPLED DRIVER & FAN)
☐ **TORSIONAL CRITICAL SPEEDS (6.7.3):**
FIRST CRITICAL ____ RPM
☐ SUBMIT X-Y PLOT (COUPLED DRIVER & FAN)
☐ TORSIONAL VIBRATION ANALYSIS FOR FAN & DRIVER
☐ TRANSIENT TORSIONAL FOR SYNCHRONOUS DRIVER UNITS
ALLOWABLE TEST LEVEL ____ mils
(Peak To Peak)
MATERIAL ____
CONSTRUCTION ____
☐ INLET BELL ____
☐ EVASE (DETAIL IN PROPOSAL) ____
◯ INSULATION REQUIRED ____ ◯ INSULATION STUDS BY: ____
☐ INSULATION TYPE ____ THICKNESS ____ in
☐ FAN HOUSING NEAR-CENTERLINE SUPPORT REQUIRED (6.2.5) ____
☐ DRAINS: NO. / SIZE ____ TYPE / LOC. ____
☐ FAN INLET ACCESS: SPLIT FOR ROTOR REMOVAL ____
☐ MANWAYS: SIZE ____ IN. TYPE / LOC. ____
SIZE ____ IN. TYPE / LOC. ____
CASING DESIGN TEMPERATURE ____ °F
BEARING HOUSING:
☐ CONSTRUCTION ____ MATERIAL ____
BEARINGS
◯ HYDRODYNAMIC ◯ ANTI-FRICTION
MOUNTING PEDESTALS ____
SOLE PLATES ____
☐ **RADIAL BEARINGS:**

	MFG. / NO.	LOAD (lbf)	LENGTH (in)	DIA (in)
INBOARD				
OUTBOARD				

DN FACTOR ____ L-10 ____ HRS.
LOAD FACTOR ____
MAX. SPEED ____ RPM @ ____ °F
CLEARANCE ____ in
BEARING SPAN (CL - CL) ____ in
☐ **THRUST BEARINGS:**
TYPE (DUEL BELL, FLAT LAND, TAPERED LAND, TILTED PAD)
____
MFG. / No. ____ AREA ____ in²
LOADING (PSI): ACTUAL ____ ALLOW. ____
Dn FACTOR ____ L-10 ____ HRS.
LOAD FACTOR ____
MAX. SPEED ____ RPM @ ____ °F
☐ THRUST COLLAR (On Inboard Bearing): TYPE: ____
TYPE ATTACHEMENT: ____
____
◯ INTEGRAL THRUST COLLAR REQUIRED (6.8.4.2.2)

ACCESSORIES:
◯ TEMP. DETECTORS (METAL) (OIL) ◯ THRUST ◯ JOURNAL
TYPE ____ MFG. / NO. ____ ◯ API 670
◯ END SEALS ____
◯ THERMOSTATICALLY CONTROLLED HEATER ____
☐ TYPE ____ MFG. / NO. ____
LUBRICATION: ____
COOLANT REQUIRED ☐ NONE ☐ AIR
☐ WATER ____ gpm @ ____ °F
☐ **ROTOR:**
SHAFT LENGTH (in) ____ DIA. @ WHEEL ____ in
MATERIAL ____
CONSTRUCTION ____
TIR @ SLEEVE ____ in DIA. @ BEARING ____ in
☐ **BLADES:**
NO. OF BLADES ____ DIAMETER (in) ____
TYPE (HOLLOW OR SOLID AIRFOIL, SINGLE THICKNESS, ETC.
____
TYPE FABRICATION ____
MATERIAL ____ COATING TYPE ____
WEAR PLATES - ____ MATERIAL ____
HUB: ____
MATERIAL ____ CONSTRUCTION ____
ROTOR WT. (lb) ____ WR² (lbf/ft²) ____
KEY WAY: NO. ____ DIM. ____ x ____ x ____ in
◯ MAX. HEATING / COOLING RATE ____ / ____ °F/MIN
MAX ALL. HEAT/COOLING RATE ____ / ____ °F/MIN
☐ **SHAFT SLEEVES:**
LENGTH (in) ____ DIA. (in) ____
SHRINK FIT ____ ☐ CORROSION RESISTANT MATL.
☐ **SHAFT SEALS:**
TYPE ____ MATERIAL ____
BUFFER OR EDUCTOR CONNECTIONS ____
DETAILS: ____
☐ **MAIN CONNECTIONS (6.3)**
INLET: NO. ____ SIZE ____ x ____ AREA (ft²) ____
☐ FLANGE SIZE ____ BOLTING ____
◯ LOCATION / ORIENTATION ____
☐ EXP. JOINT REQ'D ____ FURN. BY ____
OUTLET: SIZE ____ x ____ AREA (ft²) ____
☐ FLANGE SIZE ____ BOLTING ____
◯ LOCATION / ORIENTATION ____
☐ EXP. JOINT REQ'D ____ FURN. BY ____
◯ MATING FLG BY VENDOR ◯ ASME B16.5 ◯ ASME B16.47
☐ **OTHER CONNECTIONS (6.3)**

SERVICE	NO.	SIZE	RATING	FACING
LUBE OIL INLET				
LUBE OIL OUTLET				
COOLING WATER INLET				
COOLING WATER OUTLET				
PRESSURE GAGE				
TEMP. GAGE				
CONDENSATE DRAINS				

JOB NO. ____ ITEM NO. ____
REVISION NO. ____ DATE ____
PAGE ____ OF ____ BY ____

CENTRIFUGAL FAN (API 673, THIRD EDITION)
DATASHEET
U.S. CUSTOMARY UNITS

CONSTRUCTION FEATURES (Continued)

NOISE ATTENUATION:

- MAX. ALLOW SOUND PRESS LEVEL ____ DBA @ ____ ft
- PREDICTED SOUND PRESS LEVEL ____ DBA @ ____ ft
- ATTENUATION METHOD ____
- FURNISHED BY ____
- SILENCER MFG / MODEL NO. ____
  - ACOUSTIC PERF ____
  - AERODYNAMIC PERF ____ CFM ____ °F
  - LOSS ____ in WG
- ACCESSORIES ____

FAN CLEANING SYSTEM (6.1.33):

- REQUIRED ____ CLEANING MEDIUM ____
- MFR. / MODEL ____ FURN BY ____
- INSTALLED BY ____
- DETAILS / DWG. NO. ____

BASEPLATES & SOLEPLATES:

- TRI-DIRECTIONAL ADJUSTING SCREWS FOR EQUIP.
- PILOT HOLES FOR DOWELS
- TYPE GROUT ____ TYPE PRECOAT ____
- SOLEPLATES FOR: BEARING PEDESTALS / GEAR / DRIVER / FAN HOUSING SUPPORTS
- BASE PLATE:
  - COMMON (Under Fan, Gear, Driver) / FAN ALONE
  - OTHER / DIMENSIONS ____ x ____ x ____ ft
  - DECKING: NON SKID / OPEN CONSTRUCTION
  - DRIP RIM / OPEN DRAIN
  - SUITABLE FOR: COLUMN or PERIMETER SUPPORT
- LEVELING PADS W/ REMOVABLE COVER
- SUBSOLE PLATES REQUIRED

FAN ITEMS:	CORROSION ALLOWANCE	SIZE / THICKNESS (INCL. C.A.)	MATERIAL	MATERIAL SPECIFICATION
SHAFT				
BLADES				
HUB				
CENTER PLATE				
SHROUDS				
SLEEVES				
SEALS				
HOUSING				
DAMPERS				
CUIDE VANES				
RAIN HOODS				
INLET BELLS				
EVASE (DISCH., DIFFUSER)				
SOUND TRUNK				
INLET DUCT				
WEAR PLATES				

COUPLINGS:	DRIVER - FAN	GEAR - FAN	DRIVER - GEAR
COUPLING & GUARD FURNISHED BY:			
TYPE			
MFG.			
MODEL / NUMBER			
LUBRICATION			
MOUNT CPLG HALVES			
- FAN			
- DRIVER			
- GEAR			
SPACER LENGTH			
LTD. END FLOAT REQ'D			
COUPLING GUARD REQ'D			
SERVICE FACTOR			
CPLG RATING HP / 100 RPM			
KEYED or HYDR FIT			
ADAPTER (Solo) PLATE			
MATERIALS			

JOB NO. ______ ITEM NO. ______

REVISION NO. ______ DATE ______

PAGE ______ OF ______ BY ______

CENTRIFUGAL FAN (API 673, THIRD EDITION) DATASHEET U.S. CUSTOMARY UNITS

CONSTRUCTION FEATURES (Continued)

☐ ALLOWABLE EXTERNAL LOADS

	INLET		DISCHARGE	
	FORCE lbf	MOMENT ft-lbf	FORCE lbf	MOMENT ft-lbf
AXIAL				
VERTICAL				
HORIZ. 90°				

VIBRATION DETECTORS:

○ PROVISIONS FOR VIBRATION TRANSDUCERS (THREADED CONN.)

○ FLAT SURFACES FOR MAGNETIC MOUNTED TRANSDUCERS

○ SEISMIC SENSORS COVER (S) BY ______

○ PROVISIONS FOR MOUNTING NON-CONTACTING VIB. PROBES

○ PER API 670

SPEED DETECTORS (On Ooutboard Bearing):

○ NON-CONTACT PROBE ○ SPEED SWITCH

○ OTHER ______

○ TYPE ______ ☐ MODEL ______

○ MFG ______

○ LOCATION ______

☐ SCALE RANGE ______ RPM

SHOP INSPECTIONS & TESTS:	REQ'D	OBS'D	WIT
SHOP INSPECTION	○	○	○
CLEANLINESS INSPECTION	○	○	○
HARDNESS VERIFICATION	○	○	○
CHARPY IMPACT TESTING	○	○	○
SHAFT RUNOUT CHECK	○	○	○
ROTOR BALANCING	○	○	○
REBAL. AFTER MOUNTING CPLG.	○	○	○
RESIDUAL BALANCE CHECK	○	○	○
CALIBRATION CHECK OF BALANCING EQUIP.	○	○	○
NDT EXAMINATION	○	○	○
ASSEMBLY & FIT UP CHECK	○	○	○
INITIAL &/OR FINAL ALIGN	○	○	○
GEAR TOOTH CONTACT CHECK (API 677)	○	○	○
MECHANICAL RUN TEST	○	○	○
FULL UNIT MECHANICAL RUN TEST	○	○	○
VIBRATION TEST	○	○	○
SOUND LEVEL TEST	○	○	○
MAT'L CERTIFICATION	○	○	○
SURFACE & SUBSURFACE INSPECTION	○	○	○
TYPE ______			
PRESSURE TEST	○	○	○
- HOUSING	○	○	○
- DUCTING	○	○	○
- LUBE OIL SYSTEM	○	○	○
RUN & CHECK LUBE CONSOLE	○	○	○
SHOP PERFORMANCE TEST	○	○	○
PRE-SHIPMENT INSPECTION	○	○	○
- DRIVER/AUX. MOUNTED	○	○	○
QUALITY CONTROL REVIEW	○	○	○
FIELD PERFORMANCE TEST	○	○	○
OTHERS: ______	○	○	○
______	○	○	○
______	○	○	○

☐ WEIGHTS LBS:

FAN ______ DRIVER ______ BASE ______

ROTORS FAN ______ DRIVER ______ GEAR ______

GEAR UPPER CASE ______

SOUND TRUNK ______ EVASE ______

SYSTEMS: LUBE ______ CLEANING ______

CONTROL PANEL ______

MAX. FOR MAINTENANCE (IDENTIFY) ______

TOTAL SHIPPING WEIGHT ______

☐ SPACE REQUIREMENTS (FEET & INCHES)

COMPLETE UNIT L ______ W ______ H ______

CONTROL PANEL L ______ W ______ H ______

______ L ______ W ______ H ______

UTILITY REQUIREMENTS:

STEAM ______ WATER ______ ELECTRIC ______

MISCELLANEOUS:

○ VENDOR'S REVIEW & COMMENTS ON FOUNDATION DESIGN

○ VENDOR'S REVIEW & COM'TS ON CONTRACTOR'S DUCT DESIGN

○ TORSIONAL ANALYSIS REPORT REQUIRED

○ TURNING GEAR, TYPE DRIVER ______

○ AUTO ○ MANUAL ENGAGE ○ START FROM REST

○ RAINHOOD & CAP

○ INLET AIR FILTER

○ INLET DAMPER

○ INLET GUIDE VANE

○ INLET TRASH SCREEN

○ OUTLET DAMPER

○ SOUND TRUCK (INLET BOX / SILENCER)

○ BOLTING & GASKETS

REMARKS: ______

CENTRIFUGAL FAN (API 673, THIRD EDITION)
DATASHEET
U.S. CUSTOMARY UNITS

JOB NO. ________ ITEM NO. ________
REVISION NO. ________ DATE ________
PAGE ____ OF ____ BY ________

INSTRUMENTATION

○ PER API 614 ○ OTHER

LOCAL CONTROL PANEL:

FURNISHED BY: ☐ VENDOR ☐ PURCHASER ☐ OTHERS
☐ BASE MOUNTED ☐ FREE STANDING ☐ WEATHERPROOF ☐ TOTALLY ENCLOSED ☐ EXTRA CUTOUTS
☐ VIBRATION ISOLATORS ☐ STRIP HEATERS ☐ PURGE CONNECTIONS ☐ WITH DOORS
☐ ANNUNCIATOR WITH FIRST OUT INDICATION LOCATED ON LOCAL PANEL
☐ CUSTOMER CONNECTIONS BROUGHT OUT TO TERMINAL BOXES BY VENDOR
REMARKS: ____________

INSTRUMENT SUPPLIERS:

PRESSURE GAGES:	MFR. ____	SIZE & TYPE ____
TEMPERATURE GAGES:	MFR. ____	SIZE & TYPE ____
LEVEL GAGES:	MFR. ____	SIZE & TYPE ____
DIFF. PRESSURE GAGES:	MFR. ____	SIZE & TYPE ____
PRESSURE SWITCHES:	MFR. ____	SIZE & TYPE ____
DIFF. PRESSURE SWITCHES:	MFR. ____	SIZE & TYPE ____
TEMPERATURE SWITCHES:	MFR. ____	SIZE & TYPE ____
LEVEL SWITCHES:	MFR. ____	SIZE & TYPE ____
CONTROL VALVES:	MFR. ____	SIZE & TYPE ____
PRESSURE RELIEF VALVES:	MFR. ____	SIZE & TYPE ____
SIGHT FLOW INDICATORS:	MFR. ____	SIZE & TYPE ____
VIBRATION EQUIPMENT:	MFR. ____	SIZE & TYPE ____
TACHOMETER:	MFR. ____	RANGE & TYPE ____
SOLENOID VALVES:	MFR. ____	SIZE & TYPE ____
ANNUNCIATOR:	MFR. ____	MODEL & NO. POINTS ____
☐ DAMPER / VANE ACTUATOR	MFR. ____	MODEL ____
○ FURNISHED BY: ____	☐ TYPE ____	☐ MAX. TORQUE (FT-LBS) ____

NOTE: ☐ SUPPLIED BY VENDOR ○ SUPPLIED BY PURCHASER

PRESSURE GAGE REQUIREMENTS:

FUNCTION	LOCALLY MOUNTED	LOCAL PANEL	FUNCTION	LOCALLY MOUNTED	LOCAL PANEL
FAN DISCHARGE (IN. WG)	☐ ○	☐ ○	____	☐ ○	☐ ○
CONTROL AIR (PSIG)	☐ ○	☐ ○	____	☐ ○	☐ ○
FAN SUCTION (IN. WG)	☐ ○	☐ ○	____	☐ ○	☐ ○
____	☐ ○	☐ ○	____	☐ ○	☐ ○
____	☐ ○	☐ ○	____	☐ ○	☐ ○

TEMPERATURE GAGE REQUIREMENTS:

FUNCTION	LOCALLY MOUNTED	LOCAL PANEL	FUNCTION	LOCALLY MOUNTED	LOCAL PANEL
FAN DISCHARGE PRESSURE	☐ ○	☐ ○	FAN SUCTION	☐ ○	☐ ○
DISCHARGE FROM EACH	☐ ○	☐ ○		☐ ○	☐ ○
PINION JOURNAL BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
BULL GEAR JOURNAL BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
FAN THRUST BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
DRIVER JOURNAL BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
DRIVER THRUST BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
GEAR THRUST BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
FAN JOURNAL BEARING	☐ ○	☐ ○	____	☐ ○	☐ ○
____	☐ ○	☐ ○	____	☐ ○	☐ ○

SWITCH CLOSURES:

ALARM CONTACTS SHALL: ☐ OPEN ☐ CLOSE TO SOUND ALARM AND BE NORMALLY ☐ ENERGIZED ☐ DE-ENERGIZED
SHUTDOWN CONTACTS SHALL: ☐ OPEN ☐ CLOSE TO TRIP AND BE NORMALLY ☐ ENERGIZED ☐ DE-ENERGIZED
NOTE: NORMAL CONDITION IS WHEN FAN IS IN OPERATION.

CENTRIFUGAL FAN (API 673-3RD. EDITION)
DATASHEET
U.S. CUSTOMARY UNITS

JOB NO. ________ ITEM NO. ________
REVISION NO. ________ DATE ________
PAGE ____ OF ____ BY ________

INSTRUMENTATION (Continued)

MISCELLANEOUS

ALARM AND SHUTDOWN SWITCHES SHALL BE SEPARATE.
ELECTRICAL AND INSTRUMENT CONNECTIONS WITHIN THE CONFINES OF THE FAN BASE SHALL BE BROUGHT OUT TO TERMINAL BOXES.
COMMENTS REGARDING INSTRUMENTATION: ________

ALARM & SHUTDOWN SWITCHES

FUNCTION	ALARM	TRIP	FUNCTION	ALARM	TRIP
☐ ○ FAN VIBRATION			☐ ○ HI DRIVER THRUST BRG. TEMP.		
☐ ○ FAN AXIAL POSITION			☐ ○ FAN MOTOR SHUTDOWN		
☐ ○ DRIVER VIBRATION			☐ ○ HI FAN THRUST BRG. TEMP.		
☐ ○ DRIVER AXIAL POSITION			☐ ○		
☐ ○ HI INLET AIR FILTER △P			☐ ○		
☐ ○			☐ ○		
☐ ○			☐ ○		
☐ ○			☐ ○		

MISCELLANEOUS INSTRUMENTATION:

☐ ○ SIGHT FLOW INDICATORS: EACH JOURNAL & THRUST BEARING OIL RETURN LINE
☐ ○ TEMPERATURE / PRESSURE ELECTRONIC TRANSMITTERS
☐ ○ VIBRATION READOUT EQUIPMENT
☐ ○ VIBRATION READOUT LOCATED ON: ☐ LOCAL PANEL ☐ OTHER ________
☐ ○ FAN SPEED PICK-UP DEVICES
☐ ○ FAN SPEED INDICATORS
☐ ○ FAN SPEED INDICATORS LOCATED ON: ☐ LOCAL PANEL ☐ OTHER ________
☐ ○ ALARM HORN & ACKNOWLEDGEMENT SWITCH
☐ ○ ________
☐ ○ ________
☐ ○ ________

SPECIAL PURPOSE FAN OPTIONS:

DESIGN OPTIONS

○ Lateral Critical Speed Analysis (6.7.2.2)
○ Torsional Analysis (6.7.3.1)
○ Torsional Analysis for Motor driven fans w/o Gears [6.7.3.1 e)]
○ Tranin Laterical Critical Speed Analysis (6.7.5.1.1)
○ Finite Element Analysis of Baseplate (6.7.5.1.3)
○ Residual Unbalance Check after Rotor Balance (6.7.5.2.2)
○ Vendor to provide speed measure non-contacting probe (6.8.6.1.3)
○ Provisions for mounting two radial vibration probes (7.5.2.1)
○

ACCESSORIES OPTIONS

○ General Purpose or Special Purpost Steam Turbine Driver
○

CONTROLS & INSTRUMENTATION OPTIONS

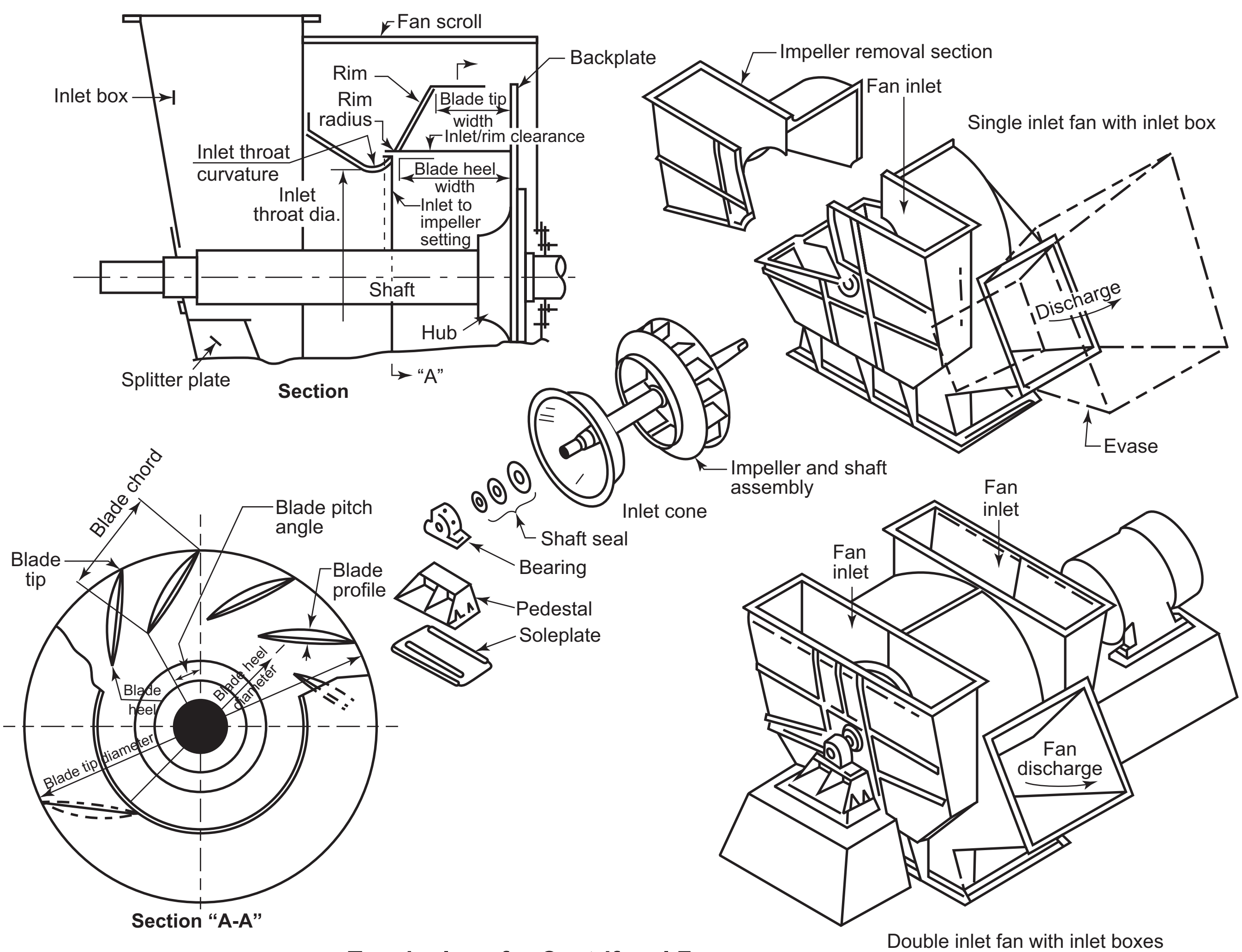
○ Provide two radial vibration (proximity) probes
○ ________
○ ________
○ ________

INSPECTION, TESTING AND PREPARATION FOR SHIPPING OPTIONS

○ Complete Unit Test with fan, gear, driver & auxiliaries
○ ________
○ ________
○ ________
○ ________

Annex B
(informative)

Terminology for Centrifugal Fans



Terminology for Centrifugal Fans

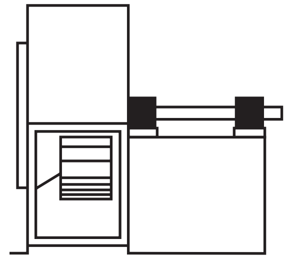
Adapted from AMCA Publication 802-02 (R2008): *Industrial Process/Power Generation Fans: Establishing Performance Using Laboratory Models*.

Annex C
(informative)

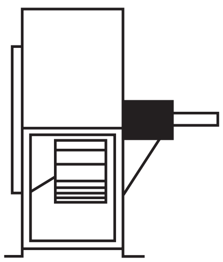
Drive Arrangements

SW – Single Width   DW – Double Width
SI – Single Inlet   DI – Double Inlet

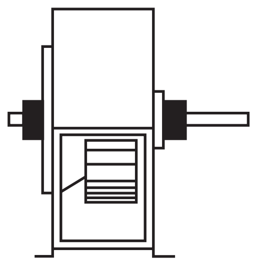
Arrangements 1, 3, 7, and 8 are also available with bearings mounted on pedestals or base set independent of the fan housing.



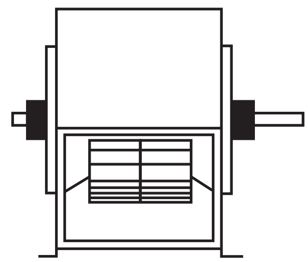
Arr. 1 SWSI: For belt drive or direct connection. Impeller overhung. Two bearings on base.



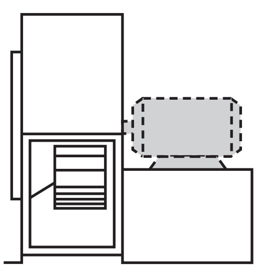
Arr. 2 SWSI: For belt drive or direct connection. Impeller overhung. Bearings in bracket supported by fan housing.



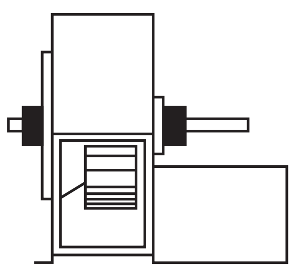
Arr. 3 SWSI: For belt drive or direct connection. One bearing on each side and supported by fan housing.



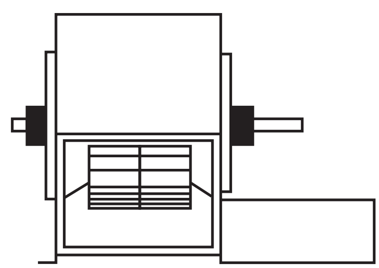
Arr. 3 DWDI: For belt drive or direct connection. One bearing on each side and supported by fan housing.



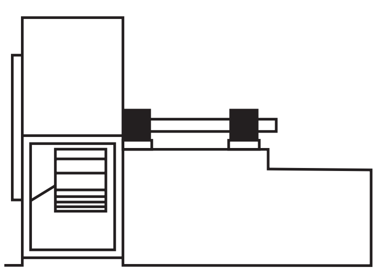
Arr. 4 SWSI: For direct drive. Impeller overhung on prime mover shaft. No bearings on fan. Prime mover base mounted or integrally directly connected.



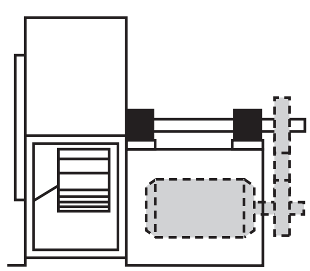
Arr. 7 SWSI: For belt drive or direct connection. Arrangement 3 plus base for prime mover.



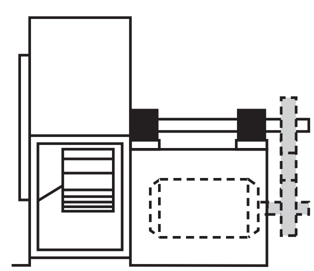
Arr. 7 DWDI: For belt drive or direct connection. Arrangement 3 plus base for prime mover.



Arr. 8 SWSI: For belt drive or direct connection. Arrangement 1 plus extended base for prime mover.

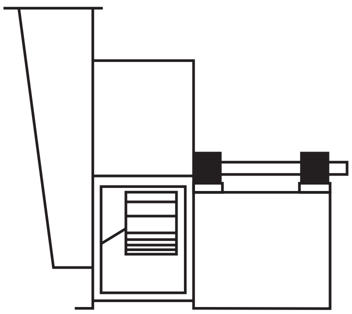


Arr. 9 SWSI: For belt drive. Impeller overhung, two bearings, with prime mover outside base.

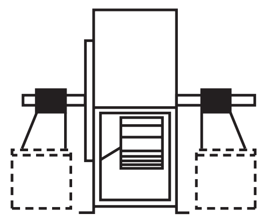


Arr. 10 SWSI: For belt drive. Impeller overhung, two bearings, with prime mover inside base.

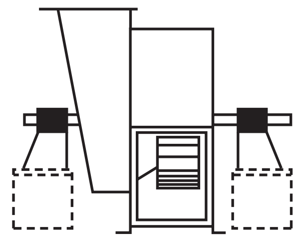
SW – Single Width DW – Double Width
SI – Single Inlet DI – Double Inlet



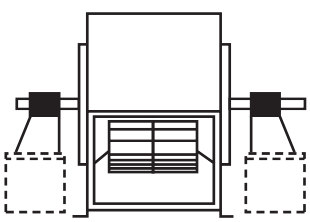
Arr. 1 SWSI with Inlet Box: For belt drive or direct connection. Impeller overhung, two bearings on base. Inlet box may be self-supporting.



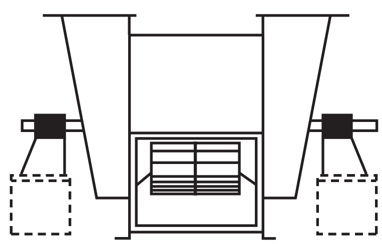
Arr. 3 SWSI with Independent Pedestal: For belt drive or direct connection fan. Housing is self-supporting. One bearing on each side supported by independent pedestals.



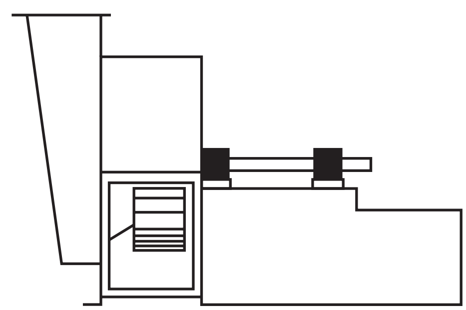
Arr. 3 SWSI with Inlet Box and Independent Pedestals: For belt drive or direct connection fan. Housing is self-supporting. One bearing on each side supported by independent pedestals with shaft extending through inlet box.



Arr. 3 DWDI with Independent Pedestal: For belt drive or direct connection fan. Housing is self-supporting. One bearing on each side supported by independent pedestals.



Arr. 3 DWDI with Inlet Box and Independent Pedestals: For belt drive or direct connection fan. Housing is self-supporting. One bearing on each side supported by independent pedestals with shaft extending through inlet box.



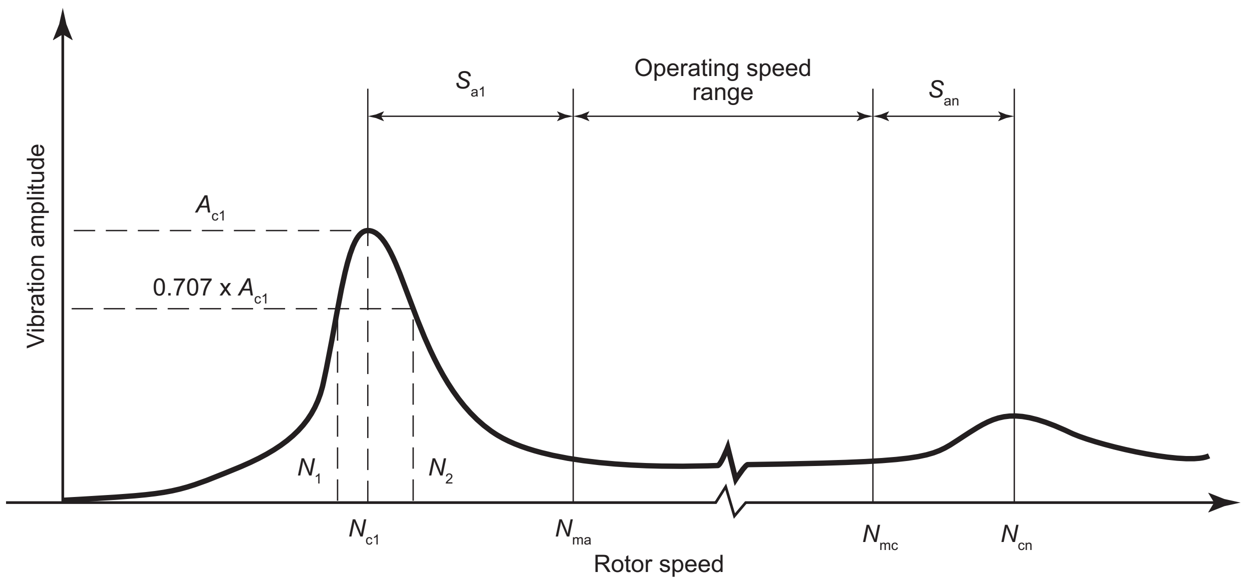
Arr. 8 SWSI with Inlet Box: For belt drive or direct connection. Impeller overhung, two bearings on base plus extended base for prime mover. Inlet box may be self-supporting.

The above arrangements are obtained from AMCA 99-2404-98, *Drive Arrangements for Centrifugal Fans.*

Annex D
(normative)

Lateral Critical Speed Analysis for Fans

D.1 The vendor shall provide a damped unbalanced response analysis for special purpose fans or if specified to ensure acceptable amplitudes of vibration at any speed from zero to trip.



N_{c1} = rotor first critical speed
N_{cn} = n^{th} critical speed
N_{ma} = minimum allowable speed
N_{mc} = maximum continuous speed

A_{c1} = amplitude at N_{c1}
N_1 = initial (lesser) speed at 0.707 x A_{c1}
N_2 = final (greater) speed at 0.707 x A_{c1}
AF_1 = amplification factor of the first critical speed
= $N_{c1} / (N_2 - N_1)$

S_{a1} = actual separation between N_{c1} and the operating speed range
S_{an} = actual separation between N_{cn} and the operating speed range
SM_{a1} = actual separation margin of first critical speed (%)
= 100 x S_{a1} / N_{ma}
SM_{an} = actual separation margin of n^{th} critical speed (%)
= 100 x S_{an} / N_{mc}

NOTE The shape of the curve is for illustration only and does not necessarily represent any actual rotor response plot.

Figure D.1—Rotor Response Plot

D.2 A separate damped unbalanced response analysis shall be conducted within the speed range of 0 to 1.5 × N_{mc}. Unbalance shall analytically be placed at the locations defined in Figure D.2. For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads. For conical (asymmetric) modes, these unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing. For overhung modes, the unbalances shall be based on the overhung mass. Figure D.2 shows the typical mode shapes and indicates the location and definition of U_a for each of the shapes. The magnitude of the unbalances shall be 2 times the value of U_r as calculated by Equations (D.1) or (D.2).

In SI units:

$$U_r = 6350W/N_{mc} \tag{D.1}$$

In USC units:

$$U_r = 4W/N_{mc} \tag{D.2}$$

where

$U_a = 2 \times U_r$ is the input unbalance for the rotordynamic response analysis in oz-in. (g-mm);

U_r is the maximum allowable residual unbalance in oz-in. (g-mm);

N_{mc} is the maximum continuous operating speed, rpm;

W is the journal static load in lbm (kg), or for bending modes where the maximum deflection occurs at the shaft ends, the overhung mass (i.e. the mass of the rotor outboard of the bearing) in lbm (kg) (see Figure D.2).

D.3 The damped unbalanced response analysis shall include but shall not be limited to the following.

NOTE The following is a list of items the analyst is to consider.

a) Rotor masses and polar and transverse moments of inertia, including coupling halves, and rotor stiffness.

b) Material properties as a function of local operating temperatures.

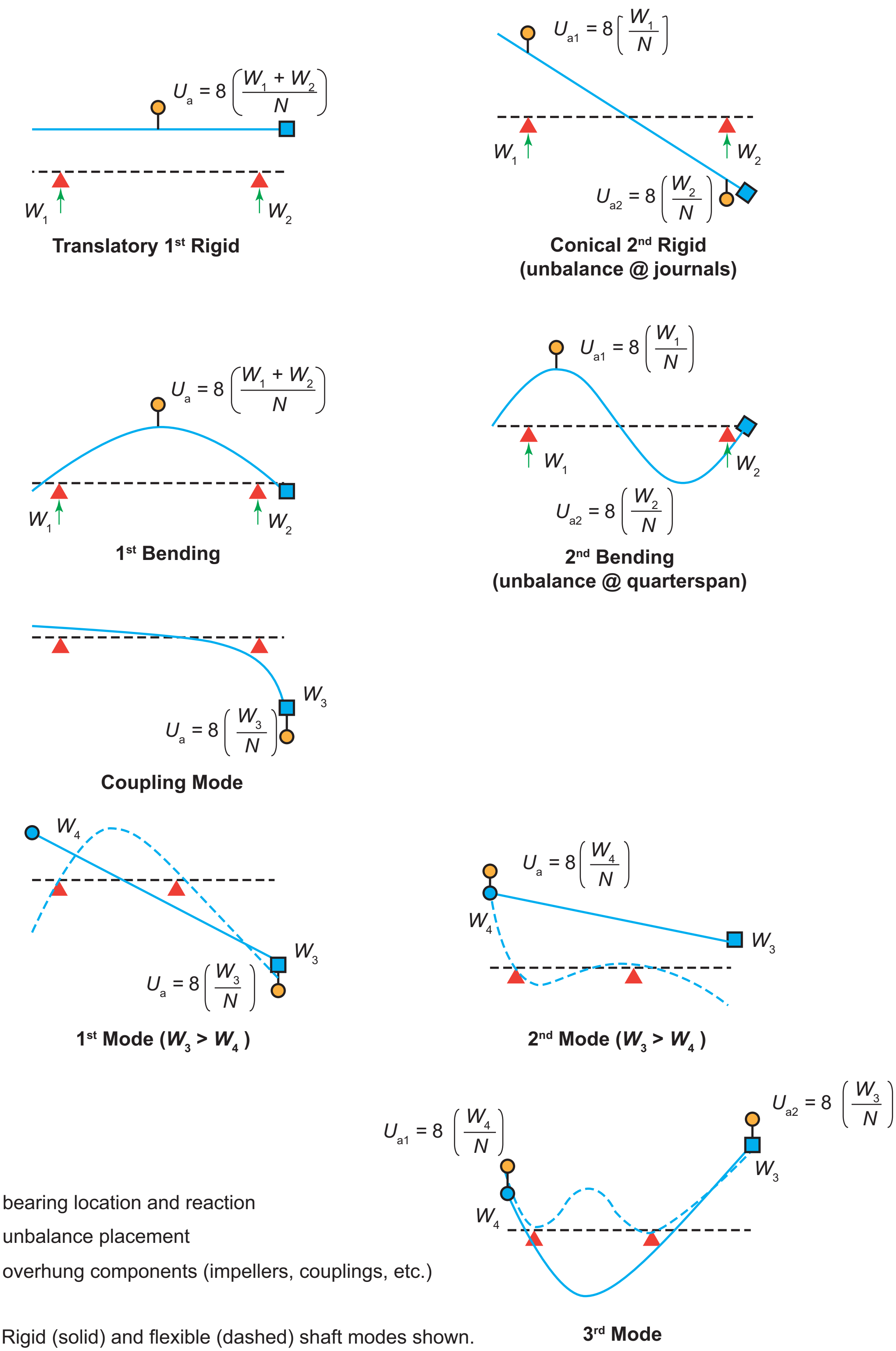
c) Bearing lubricant film stiffness and damping values including changes due to speed, load, preload, range of oil inlet temperature, and maximum to minimum clearances resulting from accumulated assembly tolerances.

d) For tilt-pad bearings, the pad pivot stiffness.

e) Structure stiffness, mass, and damping characteristics, including effects of excitation frequency over the required analysis range. For machines whose dynamic structural stiffness values are less than or equal to 3.5 times the bearing oil film stiffness values in the range from 0 to 150 % of N_{mc}, the structure characteristics shall be incorporated as an adequate dynamic system model, calculated frequency dependent structure stiffness and damping values (impedances), or structure stiffness and damping values (impedances) derived from modal or other testing. The vendor shall state the structure stiffness values used in the analysis and the basis for these values (for example, modal tests of similar rotor structure systems, or calculated structure stiffness values).

f) Rotational speed, including the various starting-speed detents, operating speed, and load ranges (including agreed upon test conditions if different from those specified), trip speed, and coastdown conditions.

g) The location and orientation of the radial vibration probes, which shall be the same in the analysis as in the machine.



Key

bearing location and reaction

unbalance placement

overhung components (impellers, couplings, etc.)

NOTE Rigid (solid) and flexible (dashed) shaft modes shown.

Figure D.2—Typical Mode Shapes

For machines equipped with rolling element bearings, the vendor shall state the bearing stiffness and damping values used for the analysis. The basis for these values or the assumptions made in calculating the values shall be presented.

D.4 As a minimum, the unbalanced response analysis shall produce the following.

NOTE The following is the list of analysis details and identifies the deliverables. The items to be considered in the analysis were identified in D.3.

a) Identification of the frequency of each critical speed in the range from 0 to 1.5 × N_{mc}.

b) Frequency, phase, and amplitude (Bode plots) at the vibration probe locations in the range 0 to 1.5 × N_{mc}, resulting from the unbalances specified in D.2. If there are no vibration probes near a bearing centerline then Bode plots shall be shown at the bearing centerline.

c) The plot of deflected rotor shape for each critical speed in the range 0 to 1.5 × N_{mc} and at N_{mc}, resulting from the unbalances specified in D.2, showing the major-axis amplitude, the centerlines of each bearing, and the locations of each radial probe.

When the support stiffness used in the analysis is less than infinite, additional Bode plots that represent the relative shaft motion and absolute bearing housing response shall be included.

D.5 The damped unbalanced response analysis shall indicate that the machine will meet the following requirement:

$$\mathrm{SM_a} \geq \mathrm{SM_r}$$

where

$\mathrm{SM_r}$ is the required separation margin, %.

a) If the AF at a particular critical speed is less than 2.5, the response is considered critically damped and no separation margin is required ($\mathrm{SM_r} = 0$).

b) If the AF at a particular critical speed is greater than or equal to 2.5 and that critical speed is below the minimum speed, the $\mathrm{SM_r}$ is given by Equation (D.3).

$$\mathrm{SM_r} = 17\left(1 - \frac{1}{\mathrm{AF} - 1.5}\right) \tag{D.3}$$

c) If the AF at a particular critical speed is greater than or equal to 2.5 and that critical speed is above the maximum continuous speed, the $\mathrm{SM_r}$ is given by Equation (D.4).

$$\mathrm{SM_r} = 10 + 17\left(1 - \frac{1}{\mathrm{AF} - 1.5}\right) \tag{D.4}$$

D.6 The calculated unbalanced peak-to-peak response at each vibration probe shall not exceed the mechanical test vibration limit of 50.8. mm (2 mil, per Table 2) or Equations (D.5) and (D.6), whichever is less, over the range of N_{ma} to N_{mc} as shown in Figure D.3.

In SI units:

$$A_1 = 25.4\sqrt{\frac{12{,}000}{N_{mc}}} \tag{D.5}$$

In USC units:

$$A_1 = \sqrt{\frac{12{,}000}{N_{mc}}} \tag{D.6}$$

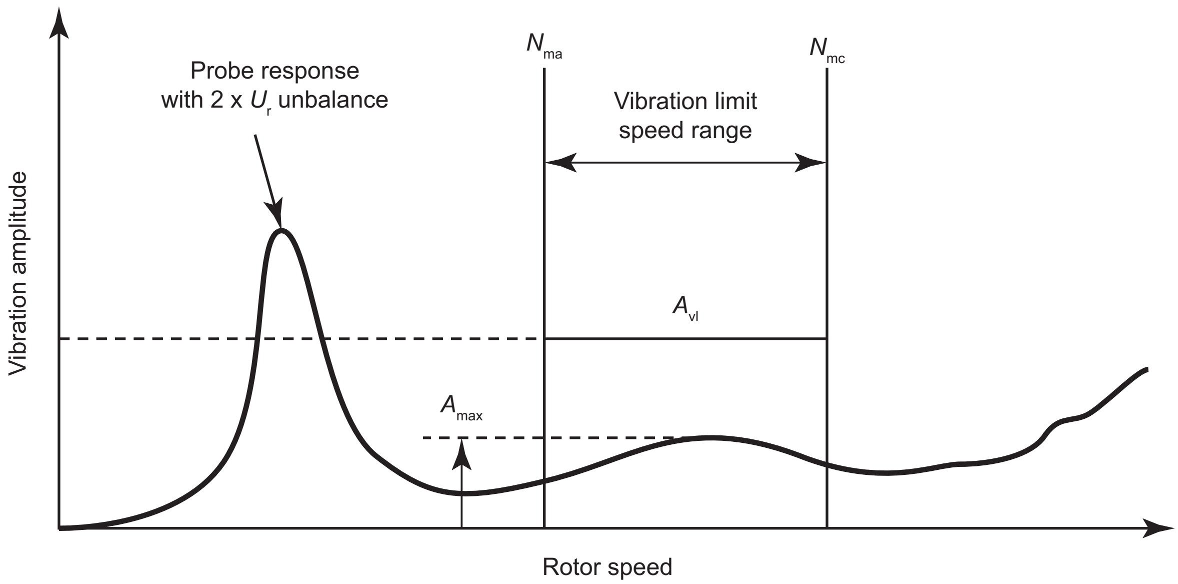


Figure D.3—Calculated Rotor Response Plot for Unbalanced Response Analysis

D.7 If the analysis indicates that the SMs still cannot be met or that a noncritically damped response peak falls within the operating speed range and the purchaser and vendor have agreed that all practical design efforts have been exhausted, then acceptable amplitudes shall be mutually agreed upon by the purchaser and the vendor. Note fan supplier should show successful operating experience with similar units. Similar units shall be interpreted to mean same speed, unit size, and dynamic behavior.

- **D.8** If specified, in addition to the other requirements of D.4, the lateral analysis report shall include the following in sufficient detail to perform an independent lateral rotor response analysis.

a) Dimensional data of the bearing design (including squeeze film dampers if specified) in sufficient detail to enable calculations of stiffness and damping coefficients. For hydrodynamic bearings and dampers, the lubricant inlet temperature range, lubricant type, and expected lubricant pressure and flow.

b) Shaft geometry with sufficient detail to model the shaft including the location of bearing centerlines and mounted components.

c) The weight, polar, and transverse moments of inertia and center of gravity of the impellers, balance piston, shaft end seals, coupling(s), and any other rotating components with significant mass, with sufficient detail to conduct an independent analysis of the rotor.

d) The input model used for the vendor's analysis.

e) The support stiffness or support model used in the analysis and its basis.

f) Location and orientation of any vibration probes.

g) Adequate design details of any other component that has a material impact on the rotor response.

- **D.9** If specified, during the mechanical running test (see Section 8), the amplitudes and phase angle of the shaft vibration from trip to slow roll speed shall be recorded after the four hour run. The recording instrumentation resolution shall be at least 0.05 mils (1.25 micron).

NOTE This set of readings is normally taken during a coastdown, with convenient increments of speed such as 50 rpm. Since at this point the rotor is balanced, any vibration amplitude and phase detected should be the result of residual unbalance and mechanical and electrical runout.

Annex E
(normative)

Procedure for Determination of Residual Unbalance

E.1 General

This annex describes the procedure to be used to determine residual unbalance in machine rotors. Although some balancing machines may be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining is to test the rotor with a known amount of unbalance.

E.2 Residual Unbalance

Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Unless otherwise specified, residual unbalance shall be expressed in g-in. (g-mm).

E.3 Maximum Allowable Residual Unbalance

E.3.1 The maximum allowable residual unbalance, per plane, shall be calculated according to the paragraph from the standard to which this annex is attached.

E.3.2 The static weight on each journal shall be determined by physical measurement. (Calculation methods may introduce errors.) It should NOT simply be assumed that that rotor weight is equally divided between the two journals. There can be great discrepancies in the journal weight to the point of being very low (even negative on overhung rotors). In the example problem, the left plane has a journal weight of 1170 lb (530.7 kg). The right plane has a journal weight of 1260 lb (571.5 kg).

E.4 Residual Unbalance Check

E.4.1 General

E.4.1.1 When the balancing machine readings indicate that the rotor has been balanced within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

E.4.1.2 To check the residual unbalance, a known trial weight is attached to the rotor sequentially in six equally spaced radial positions (60° apart), each at the same radius. [i.e. same moment (g-in.)]. The check is run at each balance machine readout plane, and the readings in each plane are tabulated and plotted on the polar graph using the procedure specified in E.4.2.

E.4.2 Procedure

E.4.2.1 Select a trial weight and radius that will be equivalent to between one and two times the maximum allowable residual unbalance [e.g. if U_{max} is 19.2 g-in. (488.4 g-mm), the trial weight should cause 19.2 g-in. to 38.4 g-in. (488.4 g-mm to 976.8 g-mm) of unbalance]. This trial weight and radius must be sufficient so that the resulting plot in E.4.2.5 encompasses the origin of the polar plot.

E.4.2.2 Starting at a convenient reference plane (i.e. ~ last heavy spot), mark off the specified six radial positions (60° increments) around the rotor. Add the trial weight near the last known heavy spot for that plane. Verify that the balance machine is responding and is within the range and graph selected for taking the residual unbalance check.

E.4.2.3 Verify that the balancing machine is responding reasonably (i.e. no faulty sensors or displays). For example, if the trial weight is added to the last known heavy spot, the first meter reading should be at least twice as much as the last reading taken before the trial weight was added. Little or no meter reading generally indicates that the rotor was not balanced to the correct tolerance, the balancing machine was not sensitive enough, or that a balancing machine fault exists (i.e. a faulty pickup). Proceed if this check is OK.

E.4.2.4 Remove the trial weight and rotate the trial weight to the next trial position (i.e. 60°, 120°, 180°, 240°, 300°, and 360° from the initial trial weight position). Repeat the initial position as a check for repeatability on the Residual Unbalance Worksheet. All verification shall be performed using only one sensitivity range on the balance machine.

E.4.2.5 Plot the balancing machine amplitude readout versus angular location of trial weight (NOT balancing machine phase angle) on the Residual Unbalance Worksheet and calculate the amount of residual unbalance (refer to worksheets, Figure E.3 and Figure E.5).

NOTE The maximum reading occurs when the trial weight is placed at the rotor's remaining heavy spot; the minimum reading occurs when the trial weight is placed opposite the rotor's heavy spot (light spot). The plotted readings should form an approximate circle around the origin of the polar chart. The balance machine angular location readout should approximate the location of the trial weight. The maximum deviation (highest reading) is the heavy spot (represents the plane of the residual unbalance). Blank worksheets are Figure E.1 and Figure E.2.

E.4.2.6 Repeat the steps described in E.4.2.1 through E.4.2.5 for each balance machine readout plane. If the specified maximum allowable residual unbalance has been exceeded in any balance machine readout plane, the rotor shall be balanced more precisely and checked again. If a balance correction is made in any balance machine readout plane, then the residual unbalance check shall be repeated in all balance machine readout planes.

E.4.2.7 For stacked component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the rotor after the addition of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

NOTE 1 This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

NOTE 2 For large multi-stage rotors, the journal reactions may be considerably different from the case of a partially stacked to a completely stacked rotor.

Customer: ____________
Job / Project Number: ____________
OEM Equipment S / N: ____________
Rotor Identification Number: ____________
Repair Purchase Order Number: ____________
Vendor Job Number: ____________
Correction Plane (Left or Right) - use sketch ____________ **(plane)**

Balancing Speed [ ] **(rpm)**
Maximum Rotor Operating Speed (N) [ ] **(rpm)**
Static Journal Weight Closest to This Correction Plane (W) [ ] **(kg)** [ ] **(lbs)**
Trial Weight Radius (R) - the radius at which the trial weight will be placed [ ] **(mm)** [ ] **(in)**

Calculate Maximum Allowable Residual Unbalance (Umax):
Si Units:
Umax = (6350) X (W) / (N) = (6350) X [ ] / [ ] = [ ] (g-mm)
Customary Units:
Umax = (113.4) X (W) / (N) = (113.4) X [ ] / [ ] = [ ] (g-in)
Calculate the trial unbalance (TU):
Trial Unbalance (TU) is between (1 X Umax) and (2 X Umax) **(1 X) to (2 X) (Selected Multiplier is)** [ ]
SI Units: [ ] **to** [ ] **=** [ ] **(g-mm)**
Customary units: [ ] **to** [ ] **=** [ ] **(g-in)**
Calculate the trial weight (TW):
Trial Weight (TW) = Umax / R = [ ] g-mm / [ ] mm or [ ] g-in / [ ] in = [ ] (g)

Conversion Information:
1kg = 2.2046 lbs 1 ounce = 28.345 grams
1 lb = 453.6 grams
Obtain the test data and complete the table:

Sketch the rotor configuration:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout Amplitude (grams)	Phase Angle (degrees)
1	0		
2	60		
3	120		
4	180		
5	240		
6	300		
Repeat 1	0		

Rotor Sketch

PROCEDURE:
Step 1: **Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure E.2) such that the largest and smallest values will fit.**
Step 2: **The points located on the Polar Chart should closely approximate a circle. If it does not, then it is probabloy that the recorded data it is in error and the test should be repeated.**
Step 3: **Determine the maximum and minimum balancing machine amplitude readings .**
Step 4: **Using the worksheet (Figure E.2), determine the Y and Z values required for the residual unbalance calculation.**
Step 5: **Using the worksheet (Figure E.2), calculate the residual unbalance remaining in the rotor.**
Step 6: **Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (Umax).**

HALF KEYS USED FOR ROTOR BALANCING
(add sketch for clarification if necessary)

Location		Weight	

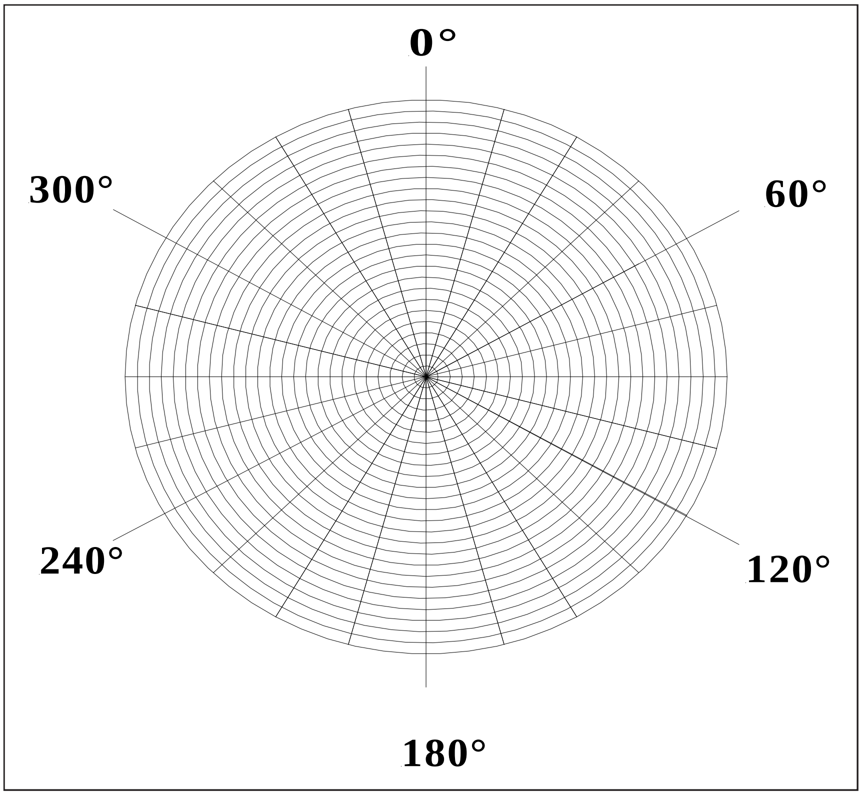
NOTES:
1) **The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).**
2) **The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.**
3) **A primary source for error is not maintaining the same radius for each trial weight location.**

Balanced By: ____________ **Date:** ________
Approved By: ____________ **Date:** ________

Figure E.1—(Blank) Residual Unbalance Worksheet

Customer: ____________
Job / Project Number: ____________
OEM Equipment S / N: ____________
Rotor Identification Number: ____________
Repair Purchase Order Number: ____________
Vendor Job Number: ____________
Correction Plane (Left or Right) - use sketch ____________

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☐ **CCW** ☐ **CW** **Phase is layed out:** ☐ **CCW** ☐ **CW**

Calculate Y and Z values:

Maximum amplitude value is:		**grams**	**Minimum amplitude value is:**			
Y = (Maximum - Minimum) / 2 (		**-**		**) / 2**	**=**	
Z = (Maximum + Minimum) / 2 (		**+**		**) / 2**	**=**	

Residual Unbalance Left in Rotor =	**(TU)**	**X**	**(Y)**	**/**	**(Z)**		
SI Units:		**X**		**/**		**=**	
Customary Units:		**X**	**S**	**/**		**=**	

Allowable Unbalance Tolerance = Umax = ________ **gm-mm** ________ **gm-in**

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance?

☐ **PASS** ☐ **FAIL**

☐ **As Received** ☐ **Final** ☐ **Other:** ________

Balanced By: ________ **Date:** ________
Approved By: ________ **Date:** ________

Figure E.2—(Blank) Residual Unbalance Polar Plot Worksheet

Customer:	ABC Refining Co.	
Job / Project Number:	00 - 1234	
OEM Equipment S / N:	C - 1234	
Rotor Identification Number:	1234 - C - 4320	
Repair Purchase Order Number:	PO 12345678	
Vendor Job Number:	Shop - 00 - 1234	
Correction Plane (Left or Right) - use sketch	Left	(plane)

Balancing Speed	800	(rpm)		
Maximum Rotor Operating Speed (N)	6900	(rpm)		
Static Journal Weight Closest to This Correction Plane (W)	530.7	(kg)	1170	(lbs)
Trial Weight Radius (R) - the radius at which the trial weight will be placed	381	(mm)	15	(in)

Calculate Maximum Allowable Residual Unbalance (Umax):

Si Units:

$$\text{Umax} = \frac{(6350) \times (W)}{(N)} = \frac{(6350) \times 530.7}{6900} = \boxed{488.4} \text{ (g-mm)}$$

Customary Units:

$$\text{Umax} = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4) \times 1170}{6900} = \boxed{19.2} \text{ (g-in)}$$

Calculate the trial unbalance (TU):

Trial Unbalance (TU) is between (1 X Umax) and (2 X Umax) (1 X) to (2 X) (Selected Multiplier is) 1.6

	(1 X)	to	(2 X)	(Selected Multiplier is)	1.6	
SI Units:	488.4	to	976.8	is	781.4	(g-mm)
Customary units:	19.2	to	38.5	is	30.8	(g-in)

Calculate the trial weight (TW):

$$\text{Trial Weight (TW)} = \frac{\text{Umax}}{R} = \frac{781 \text{ g-mm}}{381 \text{ mm}} \text{ or } \frac{31 \text{ g-in}}{15 \text{ in}} = \boxed{2.1} \text{ (g)}$$

Conversion Information:

1kg = 2.2046 lbs   1 ounce = 28.345 grams

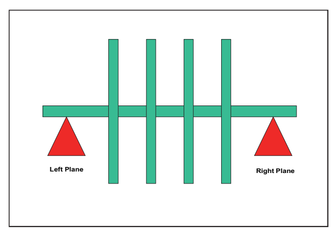
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout: Amplitude (grams)	Balancing Mach Readout: Phase Angle (degrees)
1	0	1.60	358
2	60	1.11	59
3	120	1.58	123
4	180	2.21	182
5	240	3.00	241
6	300	2.30	301
Repeat 1	0	1.58	359

Sketch the rotor configuration:

Rotor Sketch



PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure E.2) such that the largest and smallest values will fit.

Step 2: The points located on the Polar Chart should closely approximate a circle. If it does not, then it is probabloy that the recorded data it is in error and the test should be repeated.

Step 3: Determine the maximum and minimum balancing machine amplitude readings .

Step 4: Using the worksheet (Figure E.2), determine the Y and Z values required for the residual unbalance calculation.

Step 5: Using the worksheet (Figure E.2), calculate the residual unbalance remaining in the rotor.

Step 6: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (Umax).

HALF KEYS USED FOR ROTOR BALANCING
(add sketch for clarification if necessary)

Location		Weight	

NOTES:

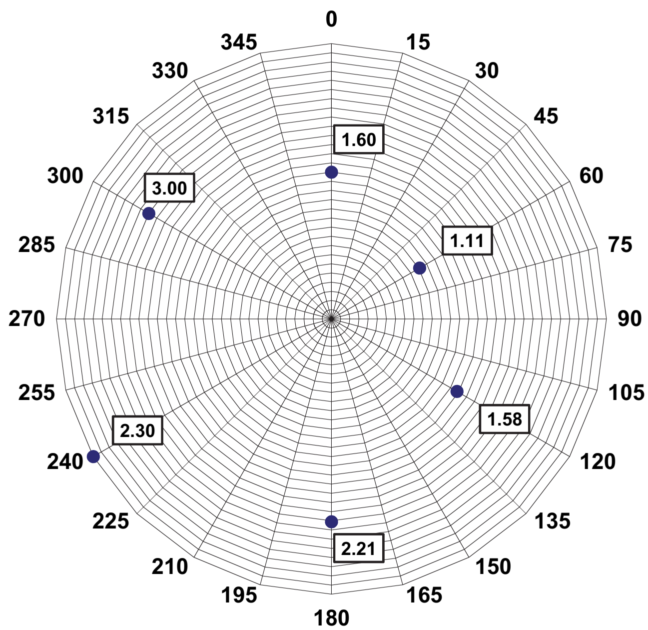
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	**Date:**	5/24/2000
Approved By:	CC	**Date:**	5/24/2000

Figure E.3—Sample Residual Unbalance Worksheet for Left Plane

Customer:	**ABC Refining Co.**
Job / Project Number:	**00 - 1234**
OEM Equipment S / N:	**C - 1234**
Rotor Identification Number:	**1234 - C - 4320**
Repair Purchase Order Number:	**PO 12345678**
Vendor Job Number:	**Shop - 00 - 1234**
Correction Plane (Left or Right) - use sketch	**Left (plane)**

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☑ **CCW** ☐ **CW** **Phase is layed out:** ☐ **CCW** ☑ **CW**

Calculate Y and Z values:

Maximum amplitude value is:	**3.00**	**grams**	**Minimum amplitude value is:**			**1.11**	**grams**
Y = (Maximum - Minimum) / 2 (	**3.00**	**-**	**1.11)**	**/ 2**	**=**	**0.9**	
Z = (Maximum + Minimum) / 2 (	**3.00**	**+**	**1.11)**	**/ 2**	**=**	**2.1**	

Residual Unbalance

Left in Rotor =	**(TU)**	**X**	**(Y)**	**/**	**(Z)**			
SI Units:	**781**	**X**	**0.95**	**/**	**2.06**	**=**	**359.3**	**g-mm**
Customary Units:	**31**	**X**	**0.95**	**/**	**2.06**	**=**	**14.1**	**g-in**

Allowable Unbalance Tolerance = Umax = **488.4** **g-mm** **19.2** **g-in**

RESULT: **Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance?** **PASS**

☐ **As Received** ☐ **Final** ☑ **Other: w/o trim hardware**

Balanced By:	**CJ, TR & RC**	**Date:**	**5/24/2000**
Approved By:	**CC**	**Date:**	**5/24/2000**

Figure E.4—Sample Residual Unbalance Polar Plot Worksheet for Left Plane

Customer:	**ABC Refining Co.**	
Job / Project Number:	**00 - 1234**	
OEM Equipment S / N:	**C - 1234**	
Rotor Identification Number:	**1234 - C - 4320**	
Repair Purchase Order Number:	**PO 12345678**	
Vendor Job Number:	**Shop - 00 - 1234**	
Correction Plane (Left or Right) - use sketch	**Right**	**(plane)**

Balancing Speed	**800**	**(rpm)**		
Maximum Rotor Operating Speed (N)	**6900**	**(rpm)**		
Static Journal Weight Closest to This Correction Plane (W)	**571.5**	**(kg)**	**1260**	**(lbs)**
Trial Weight Radius (R) - the radius at which the trial weight will be placed	**203**	**(mm)**	**8**	**(in)**

Calculate Maximum Allowable Residual Unbalance (Umax):

Si Units:

$$U_{max} = \frac{(6350) \times (W)}{(N)} = \frac{(6350) \times 571.5}{6900} = \boxed{525.9} \text{ (g-mm)}$$

Customary Units:

$$U_{max} = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4) \times 1260}{6900} = \boxed{20.7} \text{ (g-in)}$$

Calculate the trial unbalance (TU):

Trial Unbalance (TU) is between (1 X Umax) and (2 X Umax) **(1 X) to (2 X) (Selected Multiplier is)** $\boxed{1.6}$

SI Units:	**525.9**	**to**	**1051.9**	**is**	**841.5**	**(g-mm)**
Customary units:	**20.7**	**to**	**41.4**	**is**	**33.1**	**(g-in)**

Calculate the trial weight (TW):

$$\text{Trial Weight (TW)} = \frac{U_{max}}{R} = \frac{842 \text{ g-mm}}{203 \text{ mm}} \text{ or } \frac{33 \text{ g-in}}{8 \text{ in}} = \boxed{4.1} \text{ (g)}$$

Conversion Information:

1kg = 2.2046 lbs 1 ounce = 28.345 grams

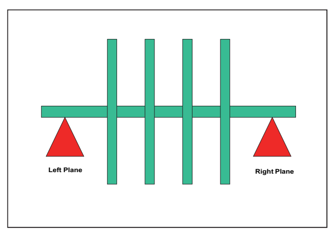
Obtain the test data and complete the table:

Test Data

Position	**Trial Weight Angular Location on Rotor (degrees)**	**Balancing Mach Readout: Amplitude (grams)**	**Balancing Mach Readout: Phase Angle (degrees)**
1	**0**	**4.60**	**3**
2	**60**	**4.20**	**58**
3	**120**	**4.70**	**121**
4	**180**	**5.20**	**180**
5	**240**	**5.80**	**235**
6	**300**	**5.10**	**301**
Repeat 1	**0**	**4.60**	**2**

Sketch the rotor configuration:

Rotor Sketch



PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure E.2) such that the largest and smallest values will fit.

Step 2: The points located on the Polar Chart should closely approximate a circle. If it does not, then it is probabloy that the recorded data it is in error and the test should be repeated.

Step 3: Determine the maximum and minimum balancing machine amplitude readings .

Step 4: Using the worksheet (Figure E.2), determine the Y and Z values required for the residual unbalance calculation.

Step 5: Using the worksheet (Figure E.2), calculate the residual unbalance remaining in the rotor.

Step 6: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (Umax).

HALF KEYS USED FOR ROTOR BALANCING
(add sketch for clarification if necessary)

Location		**Weight**	

NOTES:

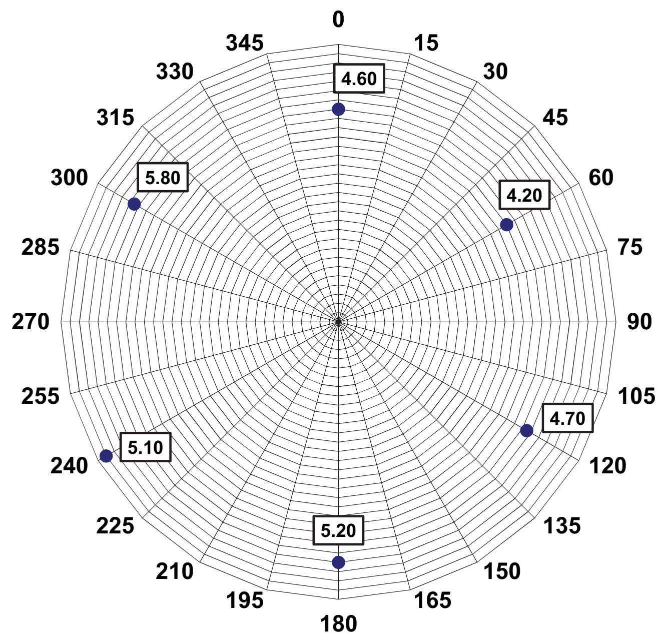
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	**CJ, TR, & RC**	**Date:**	**5/24/2000**
Approved By:	**CC**	**Date:**	**5/24/2000**

Figure E.5—Sample Residual Unbalance Worksheet for Right Plane

Customer:	ABC Refining Co.
Job / Project Number:	00 - 1234
OEM Equipment S / N:	C - 1234
Rotor Identification Number:	1234 - C - 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop - 00 - 1234
Correction Plane (Left or Right) - use sketch	Right (plane)

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☑ CCW ☐ CW **Phase is layed out:** ☐ CCW ☑ CW

Calculate Y and Z values:

Maximum amplitude value is:	5.80	grams	**Minimum ampltude value is:**			4.20	grams
Y = (Maximum - Minimum) / 2 (	5.80	-	4.20)	/ 2	=	0.8	
Z = (Maximum + Minimum) / 2 (	5.80	+	4.20)	/ 2	=	5.0	

Residual Unbalance

Left in Rotor =	**(TU)**	**X**	**(Y)**	**/**	**(Z)**			
SI Units:	842	X	0.8	/	5	=	134.6	g-mm
Customary Units:	33	X	0.8	/	5	=	5.3	g-in

Allowable Unbalance Tolerance = Umax = 525.9 g-mm 20.7 g-in

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance? **PASS**

☐ **As Received** ☐ **Final** ☑ **Other: w/o trim hardware**

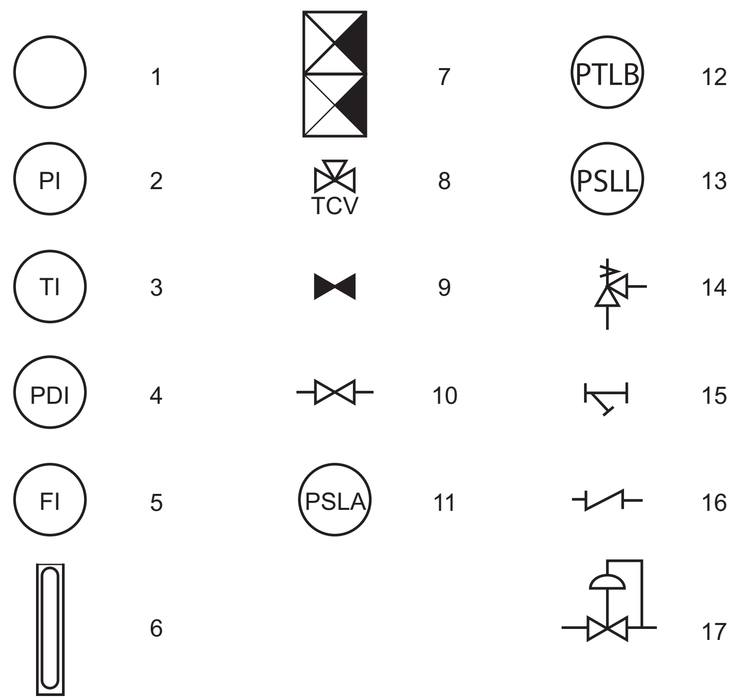
Balanced By:	CJ, TR & RC	**Date:**	5/24/2000
Approved By:	CC	**Date:**	5/24/2000

Figure E.6—Sample Residual Unbalance Polar Plot Worksheet for Right Plane

Annex F
(normative)

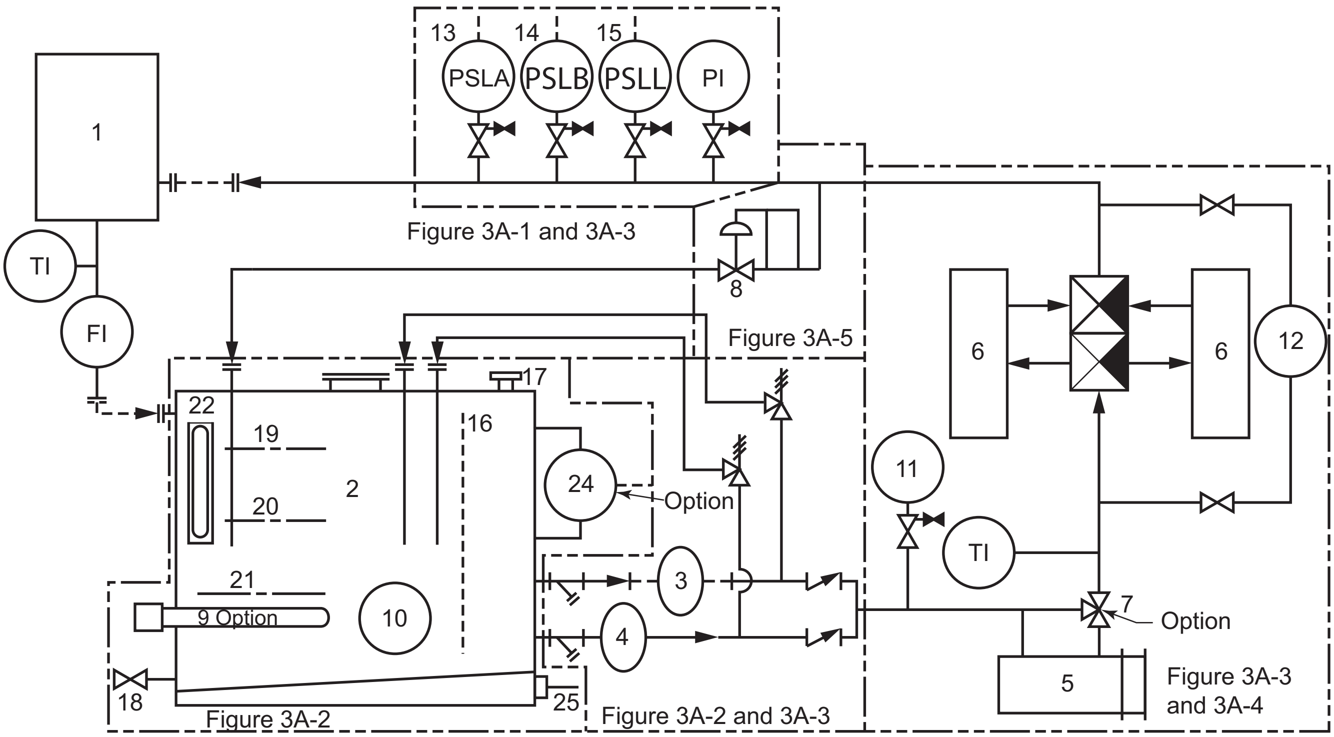
Lubrication System Schematic for General Purpose Fans

This annex contains the schematic for the standard API 673 lubrication system. This is the default lubrication system for an API 673 general purpose centrifugal fan in accordance with API 614, Ch. 3 requirements with options. The default API 673 system with or without standard options can be indicated on the API 673 datasheet. If the purchaser requires a different lubrication system, the API 614, Ch. 3 datasheets are required to be completed. The notes and key to symbols in Figure F.1 are shown below.



Key

1 instrument (letters indicate function)
2 pressure indicator
3 temperature indicator
4 pressure differential indicator
5 flow indicator
6 reflex type level indicator
7 manual three-way valve (or single transfer valve)
8 temperature control valve
9 block and bleed valve
10 block valve (gate valve)
11 low-pressure switch (auxiliary pump start)
12 low-pressure switch (alarm)
13 low-pressure switch (trip)
14 relief valve
15 line strainer
16 check valve
17 pressure control valve



Key

1 rotating equipment
2 reservoir
3 shaft driven main oil pump
4 motor driven auxiliary oil pump
5 oil cooler (3A-4 Option 1)
6 duplex oil filter (3A-4 Option 2)
7 temperature control valve (3A-4 Option 3)
8 pressure regulator (3A-5 Option 1, 2, 3, and 4)
9 heater (3A-2 Option 3)
10 temperature indicator (3A-2 Option 2)
11 pump discharge pressure indicator
12 differential pressure indicator (3A-4 Option 7)
13 auxiliary pump start signal (3A-3 Option 4)
14 low-pressure alarm signal
15 low-pressure shutdown signal (3A-3 Option 1)
16 reservoir internal baffle
17 breather (3A-2 Option 1)
18 drain valve (3A-2 Option 2)
19 maximum operation level
20 minimum operation level
21 pump suction loss level
22 level gauge
23 provision for priming (3A-3 Option 2)
24 level switch (3A-2 Option 1)
25 grounding lug (3A-2 Option 5)

NOTE The dashed boxes represent "modules" from ISO 10438.

Figure F.1—Lube Oil System Schematic

Table F.1—Lube Oil System Schematic

API 614, Ch. 3 Subclause	Note/Option	Comments
3A-1 Minimum requirements for general purpose oil systems	Add	TI, FI on oil return lines from turbine (and gear reducer and driven equipment when applicable).
3A-2 Reservoir	Option 1	A level switch is optional.
	Option 2	A temperature indicator with thermowell is required.
	Option 3	An electric immersion or steam heater is optional.
	Option 4	Additional connections are required for 1) shaft-driven oil pump relief valve return is required, 2) motor-driven oil pump relief valve return is required, 3) system PCV return, 4) auxiliary oil pump to have independent suction with strainer (strainer may be omitted for submerged pumps).
	Option 5	One tapped grounding lug is required.
	Option 6	Gauge glass (armoured and extended), is optional.
	Add	A vent (breather) with screen is required.
	Add	The reservoir shall have a sloped bottom.
	Add	A flanged drain connection with valve and blind at least 2 in. in size shall be included.
	Add	A level glass shall be provided in accordance with ISO 10438-3.
	Add	If so, the return lines from the system RVs shall discharge below the minimum operating oil level.
	Additional item	
3A-3 Pumps	Option 1	A 100 % capacity motor-driven auxiliary pump is required.
	Option 2	Block valves are not required.
	Option 3	A prelube/postlube oil pump is not required.
	Option 4	Pressure switches are required for low-pressure trip, alarm, and auxiliary pump start.
	Option 5	The pressure transmitter is not required.
	Additional item	The pressure switches shall be located in accordance with Figure F.1.
	Additional item	Shaft driven pumps may use a drilled check valve or an orificed line to prime the pump. (Not represented in Figure F.1.)

Table F.1—Lube Oil System Schematic (Continued)

API 614, Ch. 3 Subclause	Note/Option	Comments
3A-4 Pumps and coolers (and filters)	Option 1	One oil cooler is required.
	Option 2	Duplex filters are required.
	Option 3	A three-way constant temperature control valve with bypass line is optional.
	Option 4	A two or three way variable temperature control valve with bypass line is not required.
	Option 5	A temperature switch is not required.
	Option 6	A single transfer valve with cooler and filter in parallel with separate TCV is not required. Valve is not represented in Figure F.1.
	Option 7	A pressure differential indicator is required.
	Add	A single transfer valve for the duplex filters is required.
	Additional item	The replaceable filter shall be in accordance with API 614, Ch. 13.
3A-5 Pressure control	Option 1	A pressure regulator (relief valve) is required.
	Option 2	A direct acting back-pressure control valve is required.
	Option 3	Block valves around the PCV/regulator are not required.
	Option 4	A globe bypass valve is not required.

Annex G
(informative)

Centrifugal Fans Vendor Drawing and Data Requirements

This annex consists of a sample distribution record (schedule), followed by a description of the items that are presented numerically in the schedule.

DATA REQUIREMENTS
API 673 THIRD EDITION

REQUISITION NO. ____________ DATE ________
INQUIRY NO. ____________ DATE ________
PAGE 1 OF 2 BY ________
FOR ________ REVISION ________
SITE ________ UNIT ________
SERVICE ________ NO. REQUIRED ________

Proposal [a] Bidder shall furnish ________ copies of data for all items indicated by an X.

Review [b] Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.

Final [b] Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.
Vendor shall furnish ________ operating and maintenance manuals.

DISTRIBUTION RECORD

Final-Receive from vendor
Final-Due from vendor [c]
Review-Returned to vendor
Review-Received from vendor
Review-Due from vendor [c]

Proposal	Review	Final	DESCRIPTION	Review-Due from vendor	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor	Final-Receive from vendor
			1. Certified dimensional outline drawing and list of connections.					
			2. Cross-sectional drawings and bill of materials.					
			3. Rotor assembly drawings and bill of materials.					
			4. Thrust-bearing assembly drawing and bill of materials.					
			5. Journal-bearing assembly drawings and bills of materials.					
			6. Shaft sleeve and seal drawing and bill of materials.					
			7. Shaft/coupling assembly drawing and bill of materials.					
			8. Silencer(s), intake cap(s) or hood(s), trash screen(s), and transition piece(s) drawing.					
			9. Inlet damper(s)/vane(s) assembly drawing(s) and bill of materials.					
			10. Discharge damper assembly drawing and bill of materials.					
			11. Control system drawing and bill of materials.					
			12. Cleaning system drawing bill of materials.					
			13. Electrical and instrumentation schematics and bill of materials.					
			14. Electrical and instrumentation arrangement drawing and list of connections.					
			15. Lube/control oil schematic and bill of materials.					
			16. Lube oil assembly and arrangement drawing.					
			17. Lube oil component drawings and data.					
			18. Performance curves.					
			19. Vibration analysis data.					
			20. Lateral critical speed analysis (optional).					
			21. Torsional critical speed analysis.					
			22. Transient torsional analysis.					
			23. Allowable flange loadings.					
			24. Coupling alignment diagram.					
			25. Weld procedures.					
			26. Performance test log.					
			27. Mechanical run test logs.					
			28. Rotor balance logs.					
			29. Rotor mechanical and electrical runout					
			30. "As-built" datasheets.					
			31. "As-built" dimensions.					
			32. Field installation instructions.					
			33. Operating and maintenance manuals.					
			34. Spare Parts recommendation.					

[a] Proposal drawings and data do not have to be certified or "as-built."

Proposal [a] Bidder shall furnish ________ copies of data for all items indicated by an X.

Review [b] Vendor shall furnish ________ ________ transparencies of drawings and data indicated.

Final [b] Vendor shall furnish ________ copies and ________ transparencies of drawings and data indicated.
Vendor shall furnish ________ operating and maintenance manuals.

DISTRIBUTION RECORD

Final-Receive from vendor
Final-Due from vendor [c]
Review-Returned to vendor
Review-Received from vendor
Review-Due from vendor [c]

Proposal	Review	Final	MOTOR	Review-Due from vendor	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor	Final-Receive from vendor
			35. Certified dimensional outline drawing.					
			36. Cross-sectional drawing and bill of materials					
			37. "As-built" datasheet.					
			38. Performance data.					
			39. Certified drawings of auxiliary systems.					
			40. Operating and maintenance manuals.					
			41. Spare parts recommendation.					

GEAR

			42. Certified dimensional outline drawing and list of connections					
			43. Cross-sectional drawing and bill of materials.					
			44. Thrust bearing assembly drawing and bill of materials.					
			45. Journal bearing assembly drawing and bill of materials.					
			46. "As-built" datasheets.					
			47. Mechanical run test log.					
			48. Gear test logs.					
			49. Specified operational test data and reports.					
			50. Operating and maintenance manuals.					
			51. Spare parts recommendation.					

GENERAL

			52. Engineering, fabrication, and delivery schedule (progress reports).					
			53. List of drawings.					
			54. Shipping list.					
			55. Technical data manual.					
			56. Material safety datasheets.					
			57. Preservation, packaging, and shipping procedures.					
			58. Bearing babbit strength vs. temperature curves.					

[a] Proposal drawings and data do not have to be certified or as built.
[b] Purchaser will indicate in this column the desired time frame for submission of materials, using the nomenclature given at the end of the form.
[c] Bidder shall complete this column to reflect his actual distribution schedule and shall include this form with the proposal.

Notes:

1. Send all drawings and data to ________________________________
2. All drawings and data must show project, purchase order, and item numbers in addition to the plant location and unit. One set of the drawings/instructions necessary for field installation must be forwarded with shipment in addition to copies specified above.
3. See expanded description below of specified items.
4. All of the information indicated on the distributuion schedule shall be received before final payment is made.

Nomenclature:

________ S—number of weeks before shipment.
________ F—number of weeks after firm order.
________ D—number of weeks after receipt of approved drawings.

Vendor ________________________________

Date ________ Vendor Reference ________________________________

Description

1) Certified dimensional outline drawing including:
   a) the size, rating, and location of all customer connections;
   b) approximate overall handling weights;
   c) overall dimensions;
   d) shaft centerline height.
   e) dimensions of baseplates (if furnished) complete with diameter, number, and locations of bolt holes and thickness of metal through which the bolts will pass, recommended clearances, center of gravity, and details for foundation design;
   f) direction of rotation.
2) Cross-sectional drawings and bill of materials including:
   a) journal bearing clearances and tolerance,
   b) rotor float (axial),
   c) seal clearances and tolerance,
   d) outside diameter of impeller at blade tip,
   e) axial overlap of the inlet cone and impeller,
   f) radial clearance between the inlet cone and impeller.
3) Rotor assembly drawing including:
   a) axial position from a thrust collar face to:
      1. the impeller (each inlet side),
      2. each radial probe,
      3. each journal bearing centerline,
      4. the phase angle notch,
      5. coupling face or end of shaft;
   b) thrust collar assembly details including:
      1. collar-shaft fit with tolerance,
      2. concentricity (or axial runout) tolerance,
      3. the surface finish requirements for collar faces,
      4. the preheat method and temperature requirements for “shrunk-on” collar installation and removal,
      5. required torque for locknut;
   c) dimensioned shaft end(s) for coupling mounting;
   d) the bill of materials.
4) Thrust bearing assembly drawing and bill of materials.
5) Journal bearing assembly drawing and bill of materials.
6) Shaft sleeve and seal drawing and bill of materials including:
   a) sleeve-shaft fit with tolerance,

b) surface finish requirements for sleeve,

c) seal clearances and tolerances,

d) the preheat method and temperature requirements for “shrunk-on” sleeve installation and removal.

7) Shaft/coupling assembly drawing and bill of materials including allowable misalignment tolerances:

a) hydraulic mounting procedure;

b) shaft end gap and tolerance;

c) coupling guards;

d) thermal growth;

e) make, size, and serial number;

f) balance tolerance.

8) Silencer(s), intake cap(s) or hood(s), trash screen(s), and transition piece(s).

9) Inlet damper(s)/vane(s), assembly drawing(s), and bill of materials.

10) Discharge damper assembly drawing and bill of materials.

11) Fan control system drawing and bill of materials including:

a) damper positioner drawings,

b) damper positioner operating and maintenance manuals.

12) Fan cleaning system drawing and bill of materials including:

a) cleaner arrangement drawing,

b) cleaner controller assembly drawing,

c) electric wiring diagram,

d) operating and maintenance manual.

13) Electrical and instrumentation schematics and bill of materials including:

a) vibration warning and shutdown limits,

b) bearing temperature warning and shutdown limits,

c) lube oil temperature warning and shutdown limits.

14) Electrical and instrumentation arrangement drawing and list of connections.

15) Lube oil schematic and bill of materials including:

a) steady state and transient oil flows and pressures at each use point;

b) control, alarm, and trip settings (pressure and recommended temperatures);

c) heat loads at each use point at maximum load;

d) utility requirements, including electrical, water, and air;

e) pipe, valve, and orifice sizes;

f) instrumentation, safety devices, and control schemes;

g) control valve sizing coefficient (Cv).

16) Lube oil system arrangement drawing including size, rating, and location of all customer connections.

17) Lube oil component drawings and data including the following.

   a) Pumps and drivers.

      1. Certified dimensional outline drawing.
      2. Cross section and bill of materials.
      3. Mechanical seal drawing and bill of materials.
      4. Performance curves for centrifugal pumps.
      5. Instruction and operating manuals.
      6. Completed data forms for pumps and for drivers.

   b) Coolers, filters, and reservoir.

      1. Fabrication drawings.
      2. Maximum, minimum, and normal liquid levels in reservoir.
      3. Completed data form for cooler(s).

   c) Instrumentation.

      1. Controllers.
      2. Switches.
      3. Control valves.
      4. Gauges.

   d) Spare parts recommendations.

18) Performance curves including:

   a) curves for static pressure rise and horsepower versus ICFM for all operating conditions specified on datasheet,
   b) curve for speed versus starting torque.

19) Vibration analysis data including:

   a) the number of blades in the impeller,
   b) the number of teeth-gear-type couplings.

20) Lateral critical speed analysis including the following:

   a) method used,
   b) graphic display of bearing and support stiffness and its effect on critical speeds,
   c) graphic display of rotor response to unbalance (including damping),
   d) graphic display of overhung moment and its effect on critical speed (including damping),
   e) journal static loads,
   f) stiffness and damping coefficients,
   g) tilting pad geometry and configuration:

      1. pad angle,
      2. pivot clearance,
      3. pad clearance,
      4. preload.

21) Torsional critical speed analysis for equipment as specified by 6.7.3.1 the following.
   a) Method used.
   b) Graphic display of the mass-elastic system.
   c) Tabulation identifying the mass moment torsional stiffness for each component in the mass elastic system.
   d) Graphic display of exciting sources (rpm).
   e) Graphic display of torsional critical speeds and deflections (mode shape diagrams).
22) Transient torsional analysis for all synchronous motor driven units and variable frequency motors.
23) Allowable flange loading(s) for all customer connections including anticipated thermal movements referenced to a defined point.
24) A coupling alignment diagram, including recommended limits during operation. Note all shaft end position changes and support growths from 60 °F (15 °C) or another temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.
25) Weld procedures for fabrication and repair.
26) Performance test log.
27) Mechanical run test logs including but not limited to the following:
   a) oil flows, pressures, and temperatures;
   b) vibration, including x–y plot of amplitude and phase angle versus revolutions per minute during start-up and shutdown,
   c) bearing metal temperatures.
28) Rotor balance logs.
29) Rotor combined mechanical and electrical runout.
30) "As-built" datasheets.
31) "As-built" dimensions (including design tolerances) and/or data as follows.
   a) Shaft diameters at:
      1. thrust collar (for separate collars),
      2. each seal,
      3. impeller hub,
      4. each journal bearing,
      5. each coupling.
   b) Each coupling bore.
   c) Each impeller bore.
   d) Thrust collar bore (for separate collars).
   e) Each journal bearing inside diameter.
   f) Thrust bearing concentricity (axial runout).
   g) Metallurgy and heat treatment for:
      1. shaft,
      2. impeller,
      3. thrust collar(s).

h) Hardness readings on parts listed under Item 31 g) above when corrosive agents which may cause stress corrosion cracking are in the motive or process fluid.

• 32) Field installation manual describing the following (see 9.3.5.2).

a) Storage procedures.

b) Foundation plan.

c) Grouting details.

d) Setting equipment, rigging procedures, component weights, center of mass, and lifting diagrams.

e) Coupling alignment diagram (per Item 24 above).

f) Piping recommendations, including allowable flange loads.

g) Composite outline drawings for the driver/driven-equipment train including anchor bolt locations.

h) Dismantling clearances.

i) Normal and maximum utility requirements.

33) Operating and maintenance manuals describing the following.

a) Start-up.

b) Normal shutdown.

c) Emergency shutdown.

d) Operating limits, other operating restrictions, and a list of undesirable speeds (see 6.7.1.5).

e) Lube oil recommendations and specifications.

f) Routine operational procedures, including recommended inspection schedules and procedures.

g) Instruction for:

1. disassembly and reassembly of rotor in casing;
2. rotor unstacking and restacking procedures;
3. disassembly and reassembly of journal bearings (for tilting-pad bearings, the instructions shall include "go/no-go" dimensions with tolerances for three-step plug gauges).

h) Performance data, including:

1. curve showing certified shaft speed versus site rated power,
2. curve showing ambient temperature versus site rated power,
3. curve showing output-power shaft speed versus torque.

i) Vibration analysis data, per Items 19 to 22 above.

j) As-built data, including:

1. as-built datasheets;
2. as-built dimensions or data, including assembly clearances;
3. mechanical running test logs, per Item 27 above;
4. rotor balancing logs, per Item 28 above;
5. rotor mechanical and electrical runout at each journal per Item 29 above;
6. physical and chemical mill certificates for critical components;
7. test logs of all specified optional tests.

k) Drawings and data, including the following.
   1. Certified dimensional outline drawing and list of connections.
   2. Cross-sectional drawing and bill of materials.
   3. Rotor assembly drawings and bills of materials.
   4. Thrust-bearing assembly drawing and bill of materials.
   5. Journal-bearing assembly drawings and bill of materials.
   6. Seal component drawing and bill of materials.
   7. Lube oil schematics and bills of materials.
   8. Lube oil assembly drawing and list of connections.
   9. Lube oil component drawings and data.
   10. Electrical and instrumentation schematics and bills of materials.
   11. Electrical and instrumentation assembly drawings and list of connections.
   12. Governor and control system and trip system data.
   13. Trip- and throttle-valve construction drawings.
   14. Silencer(s), intake cap(s) or hood(s), trash screen(s), transition piece(s) drawing.
   15. Inlet damper(s)/vane(s) assembly drawing(s) and bill of materials.
   16. Discharge damper assembly drawing and bill of materials.
   17. Fan control system drawing and bill of materials.
   18. Fan cleaning system drawing and bill of materials.

34) Spare parts recommendation—see 9.3.

35) Certified dimensional outline drawing for motor and all auxiliary equipment including the following.
   a) The size, location, and purpose of all customer connections, including conduit, instrumentation, and any piping or ducting.
   b) ANSI rating and facing for any flanged connections.
   c) The size and location of anchor bolt holes and thickness of metal through which bolts will pass.
   d) The total weight of each item of equipment (motor and auxiliary equipment) plus loading diagrams, heaviest weight, and name of the part.
   e) Overall dimensions and all horizontal and vertical clearances necessary for dismantling purposes and the approximate location of lifting lugs.
   f) The shaft centerline height.
   g) Shaft end dimensions plus tolerances for the coupling.
   h) The direction of rotation. If suitable for rotation in both directions, the drawings shall be so marked.

36) Cross-sectional drawing and bill of materials including:
   a) bearing clearances and tolerances,
   b) the rotor float (axial),
   c) the complete parts list.

37) “As-built” datasheets.

38) Performance data including the following.

a) For induction motors 200 hp and smaller:

1. efficiency and power factor at one-half, three-quarter, and full load;
2. speed-torque curves.

b) For induction motors 250 hp and larger, certified test reports for all tests run and guaranteed performance curves as follows:

1. time-current heating curve;
2. speed-torque curves at 70 %, 80 %, 90 %, and 100 % of rated voltage;
3. efficiency and power factor curves from 0 to rated service factor;
4. current versus load curves from 0 to rated service factor;
5. current versus speed curves from 0 to rated service factor.

39) Certified drawings of auxiliary systems including:

a) wiring diagrams for each auxiliary system supplied. The drawings shall clearly indicate the extent of the system to be supplied by the manufacturer and the extent to be supplied by others.

40) Operating and maintenance manuals shall be furnished describing installation, operation, and maintenance procedures. Each manual shall include the following sections:

a) Section 1—Installation:

1. storage;
2. setting motor, rigging procedures, component weights, and lifting diagram;
3. piping and conduit recommendations;
4. composite outline drawing for motor, including anchor bolt locations;
5. dismantling clearances.

b) Section 2—Operation:

1. start-up—including check prior to start-up,
2. normal shutdown,
3. operating limits including number of successive starts,
4. lube oil recommendations.

c) Section 3—Disassembly and assembly instructions:

1. rotor in the motor,
2. journal bearings,
3. seals,

d) Section 4—Performance data required by Item 38.

e) Section 5—“As-built” data:

1. “as-built” datasheets,
2. mechanical run test logs,
3. rotor balance logs,
4. rotor mechanical and electrical runout at each journal.

f) Section 6—Drawing and data requirements:

   1. certified dimensional outline drawing for motor and all auxiliary equipment with list of connections,
   2. cross-sectional drawing and bill of materials.

41) Spare parts recommendation.

42) Certified dimensional outline drawings and list of connections including the following.

   a) The size, rating, location, and identification of all customer connections, including vents, drains, lubricating oil, conduits, and instruments.

   b) All principal dimensions, including those required for the purchaser's foundation.

   c) Overall and handling weights.

   d) Shaft centerline heights.

   e) Shaft end dimensions plus tolerances for the couplings.

   f) The direction of rotation.

   g) Location of the center of gravity of the gear unit.

   h) The size and location of anchor bolt holes and thickness of metal through which bolts will pass.

   i) Thermal and mechanical movements of casings and shafts.

43) Cross-sectional drawing and bill of materials including the following.

   a) Thrust and journal bearing clearances and tolerances.

   b) Gear and pinion float (axial).

   c) Complete parts list.

44) Thrust bearing assembly drawing and bill of materials.

45) Journal bearing assembly drawing and bill of materials.

46) "As-built" datasheets including the following.

   a) Data for torsional analysis (a dimensional sketch of each rotor showing diameters, lengths, weight moments of inertia, and torsional stiffness).

   b) Lateral critical speed reports.

47) Certified shop log of mechanical test run.

48) Gear manufacturer's standard test logs including gear contact test data.

49) Specified optional test data and reports as mutually agreed to by the purchaser and gear manufacturer.

50) Operating and maintenance manuals shall be furnished describing installation, operation, and maintenance procedures. Each manual shall include the following sections:

   a) Section 1—Installation:

      1. storage;
      2. setting gear, rigging procedures, component weights, and lifting diagram;
      3. piping recommendations;
      4. composite outline drawing for gear, including anchor bolt hole locations;
      5. dismantling clearances;
      6. thermal and mechanical movements of casing and shaft.

b) Section 2—Operation:
   1. start-up—including final tests and checks,
   2. normal shutdown,
   3. operating limits,
   4. routine operational procedures,
   5. lube oil recommendations.
c) Section 3—Disassembly and assembly instructions:
   1. rotors in casing,
   2. journal bearings,
   3. thrust bearings,
   4. thrust collars,
   5. seals.
d) Section 4—“As-built” data:
   1. “as-built” datasheets,
   2. lateral critical speed report,
   3. mechanical run test logs,
   4. standard test logs,
   5. specified optional test data and reports.
e) Section 5—Drawing and data requirements:
   1. certified dimensional outline drawing and list of connections,
   2. cross-sectional drawing and bill of materials,
   3. thrust bearing assembly drawing and bill of materials,
   4. journal bearing assembly drawing and bill of materials.

51) Spare parts recommendation.

52) Progress reports and delivery schedule, including vendor buy-out and milestones. The reports shall include engineering, purchasing, manufacturing, and testing schedules for all major components. Planned and actual dates and the percentage completed shall be indicated for each milestone in the schedule.

53) List of drawings, including latest revision numbers and dates.

54) Shipping list, including all major components that will ship separately.

55) Technical data manual, including the following:
   a) “as-built” purchaser datasheets, per Item 30 above;
   b) certified performance curves, per Item 18 above;
   c) drawings in accordance with 9.3.2;
   d) “as-built” assembly clearances;
   e) spare parts list, in accordance with 9.3.4;
   f) vibration data, per Item 19 above;
   g) report, per Items 20, 21, 22, 24, 26, 27, 28, and 29 above;

h) API datasheets.

56) Material safety datasheets (OSHA form 20).

57) Preservation, packaging, and shipping procedures.

58) Bearing Babbitt strength versus temperature curves.

EXPLORE SOME MORE

Check out more of API's certification and training programs, standards, statistics and publications.

API Monogram™ Licensing Program

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: certification@api.org
Web: www.api.org/monogram

API Quality Registrar (APIQR™)

- ISO 9001
- ISO/TS 29001
- ISO 14001
- OHSAS 18001
- API Spec Q1®
- API Spec Q2™
- API Quality*Plus*™
- Dual Registration

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: certification@api.org
Web: www.api.org/apiqr

API Training Provider Certification Program (API TPCP®)

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: tpcp@api.org
Web: www.api.org/tpcp

API Individual Certification Programs (ICP™)

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: icp@api.org
Web: www.api.org/icp

API Engine Oil Licensing and Certification System (EOLCS™)

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: eolcs@api.org
Web: www.api.org/eolcs

Motor Oil Matters™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: motoroilmatters@api.org
Web: www.motoroilmatters.org

API Diesel Exhaust Fluid™ Certification Program

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: apidef@api.org
Web: www.apidef.org

API Perforator Design™ Registration Program

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: perfdesign@api.org
Web: www.api.org/perforators

API WorkSafe™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: apiworksafe@api.org
Web: www.api.org/worksafe

API-U®

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: training@api.org
Web: www.api-u.org

API eMaintenance™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: apiemaint@api.org
Web: www.apiemaintenance.com

API Standards

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Email: standards@api.org
Web: www.api.org/standards

API Data™

Sales: 877-562-5187
(Toll-free U.S. and Canada)
(+1) 202-682-8041
(Local and International)
Service: (+1) 202-682-8042
Email: data@api.org
Web: www.api.org/data

API Publications

Phone: 1-800-854-7179
(Toll-free U.S. and Canada)
(+1) 303-397-7956
(Local and International)
Fax: (+1) 303-397-2740
Web: www.api.org/pubs
global.ihs.com

AMERICAN PETROLEUM INSTITUTE

1220 L Street, NW
Washington, DC 20005-4070
USA

202-682-8000

Additional copies are available online at www.api.org/pubs

Phone Orders:	1-800-854-7179	(Toll-free in the U.S. and Canada)
	303-397-7956	(Local and International)
Fax Orders:	303-397-2740	

Information about API publications, programs and services is available on the web at www.api.org.

Product No. C67303