Brushless Synchronous Machines—500 kVA and Larger

API STANDARD 546
THIRD EDITION, SEPTEMBER 2008

Brushless Synchronous Machines—500 kVA and Larger

Downstream Segment

API STANDARD 546
THIRD EDITION, SEPTEMBER 2008

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.

Foreword

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.

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.

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, N.W., Washington, D.C. 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 and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

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

Contents

Page

Brushless Synchronous Machines—500 kVA and Larger

1 General

1.1 Scope

1.1.1 This standard covers the minimum requirements for form-wound and bar-wound brushless synchronous machines for use in petroleum, chemical and other industrial applications. This standard includes synchronous motors and generators with two different rotor designs:

a) salient-pole type rotors with solid or laminated poles;

b) cylindrical type rotors with solid or laminated construction.

NOTE 1 A round bullet (●) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets (see Annex A or Annex B); otherwise it should be stated in the quotation request or in the order.

NOTE 2 This standard may be applied to adjustable speed motors with appropriate attention to the specific requirements of such applications. A diamond bullet (♦) at the start of a paragraph indicates additional requirements for motors applied with adjustable speed drives (ASDs).

1.1.2 This standard requires the purchaser to specify details and features. The purchaser shall complete the data sheets in Annex A or Annex B.

NOTE Guidance for completion of the data sheets is provided in Annex D and Annex E.

1.1.3 This standard requires the vendor to complete the details and features in the vendor section of the Annex A or Annex B data sheets. (See Section 6.)

1.2 Alternative Designs

The vendor may offer alternative designs in accordance with 6.2.8.

1.3 Dimensions and Standards

● **1.3.1** Both the SI and U.S. customary system of units and dimensions are used in this standard. Data, drawings, and hardware (including fasteners) related to equipment supplied to this standard shall use the system of units specified by the purchaser. An alternate system of units for hardware (including fasteners and flanges) may be substituted as mutually agreed upon by the purchaser and the vendor.

● **1.3.2** This document recognizes two different systems of standards for the manufacturing and testing of electrical machines: American National Standards Institute (ANSI), Institute of Electrical and Electronics Engineers (IEEE), and National Electrical Manufacturers Association (NEMA); or International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO). The North American standards are the base documents. When specified by the purchaser, the corresponding international standards are acceptable for use as alternatives; however, this must not be construed that they are identical to the North American standards.

NOTE The purchaser should be aware that specific requirements contained within corresponding standards may differ.

1.4 Conflicting Requirements

In case of conflict between the inquiry, order, this document and any referenced standards, the information in the inquiry, or order after purchase, shall govern over this document, while this document shall govern over any referenced standards.

1.5 Definition of Terms

1.5.1
accelerating torque
The difference between the input torque to the rotor (electromagnetic for a motor or mechanical for a generator) and the sum of the load and loss torque; the net torque available for accelerating the rotating parts.

1.5.2
adjustable speed drive
ASD
Refers to the electronic equipment used to regulate the operating speed of the motor and driven equipment by controlling the frequency and voltage.

NOTE Other terms commonly used are variable speed drive (VSD), adjustable frequency drive (AFD), and variable frequency drive (VFD), however, use of these terms is discouraged.

1.5.3
cold start
A motor start that occurs when the rotor and stator are initially at ambient temperature.

1.5.4
hot start
Any restart of the motor that occurs when the motor is at a temperature above ambient temperature.

1.5.5
lateral critical speed
A shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

NOTE The basic identification of critical speeds is made from the natural frequencies of the system and of the forcing phenomena. If the frequency of any harmonic component of a periodic forcing phenomenon is equal to or approximates the frequency of any mode of rotor vibration, a condition of resonance may exist. If resonance exists at a finite speed, that speed is called a critical speed. This standard is concerned with actual resonant speeds rather than various calculated values. *Actual critical speeds* are not calculated values but are critical speeds confirmed by test-stand data. Critical speeds above the maximum test speed are calculated damped values.

1.5.6
locked-rotor torque of a motor
The minimum torque that it will develop at rest for all angular positions of the rotor with rated voltage applied at rated frequency.

1.5.7
owner
The final recipient of the equipment who may delegate another agent as the purchaser of the equipment.

1.5.8
power factor
PF
The ratio of kilowatt input to kilovolt-ampere input for a motor or the ratio of kilowatt output to kilovolt-ampere output for a generator.

1.5.9
pressure lubrication
The term “pressure-lubrication” applies to bearings that are either lubricated by filling the bearing with pressurized oil or bearings that are lubricated by oil directed at the bearing surfaces. This pressurized oil source may be either connected to or independent of the machine. Pressure-lubricated bearings utilize oil from a system with pump(s) and a separate reservoir, and may include filters and coolers.

1.5.10
pull-in torque
The maximum constant torque of a synchronous motor under which the motor will pull the connected load inertia into synchronism at the rated voltage and frequency when the field excitation is applied.

1.5.11
pull-out torque
The maximum sustained torque of a synchronous motor that the motor will develop at synchronous speed with the rated voltage, frequency and excitation applied.

1.5.12
pulsating torque
The single amplitude oscillatory torque of a synchronous motor that is superimposed on the mean uniform starting torque developed by the motor. The frequency of this torque oscillation is twice the rotor-slip frequency and thus decreases linearly (at the usual rated frequencies of 50 Hertz or 60 Hertz) from 100 Hertz or 120 Hertz to 0 Hertz as the speed increases from zero to synchronous speed.

1.5.13
purchaser
The agency that issues the order and specification to the vendor.

1.5.14
self-lubrication
Self-lubricated hydrodynamic bearings utilize rotation of the shaft to continuously apply lubricant to the bearing surfaces from an oil reservoir located beneath the bearing. Self-lubricated bearings include bearings partially immersed in the oil reservoir and bearings with rings in contact with the shaft.

1.5.15
service factor
A multiplier applied to the rated power of an ac motor, which indicates an increased power loading that may be carried under the conditioning specified for the service factor (see NEMA MG1).

NOTE The user should be aware that for service factors above 1.0 the machine will run at an increased temperature and insulation life will be adversely affected.

1.5.16
special tool
A tool that is not a commercially available catalog item.

NOTE For definition of synchronous machine characteristic data see ANSI/IEEE 100 or IEC 60034-4.

1.5.17
stator shift
Where the stator assembly is axially re-located on the soleplate or base without removing the outboard bearing. This exposes the rotor poles to facilitate maintenance or removal.

1.5.18
torsional critical speeds
Resonant frequencies of the complete mass-elastic system in the drive train including couplings and driven equipment.

NOTE The first torsional natural frequency of synchronous-motor/driven-equipment combinations normally lies between twice the line frequency and zero frequency and may be excited from the motor or driven equipment. This means that at least the first torsional critical speed is traversed each time such a drive train is started. Depending on the mechanical characteristics of the drive train, at the resonant speed defined by the intersection of the natural torsional frequency and the frequency of the torque oscillations, the torque oscillation may be escalated to a point at which unacceptably high torsional stress occurs in the rotating system if there is not sufficient damping within the system.

1.5.19
trip speed (in revolutions/min)
The speed at which the independent emergency speed device operates to shut down the machine.

1.5.20
unit responsibility
Refers to the responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order. The technical aspects to be considered include but are not limited to such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications and testing of components.

1.5.21
vendor (also known as supplier)
The agency that supplies the equipment.

1.5.22
vibration forcing phenomena
Excitation forces that may cause vibration. The exciting frequency may be less than, equal to, or greater than the synchronous frequency of the rotor. Potential excitations to be considered in the design of the system shall include but are not limited to the following sources:

a) mechanical unbalance in the rotor system;

b) oil-film instabilities (whirl or whip);

c) alignment tolerances;

d) gear problems such as unbalance and pitch line runout;

e) start-up condition frequencies;

f) twice the line frequencies;

g) electrical unbalance;

h) mechanical pulsations produced by the motor load;

i) short-circuits (faults) and other transient conditions on the electrical system;

j) ASDs; and

k) electrical exciting pulsating torque with double slip frequency due to rotor saliency.

1.6 Referenced Publications

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 the vendor.

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*

API Recommended Practice 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1 and Zone 2*

API Standard 614, *Lubrication, Shaft-Sealing, and Control-Oil Systems and Auxiiliaries for Petroleum, Chemical and Gas Industry Services*

API Standard 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*

API Standard 670, *Machinery Protection Systems*

API 671, *Special-Purpose Couplings for Petroleum, Chemical and Gas Industry Services*

API Recommended Practice 684, *Tutorial on the API Standard Paragraphs Covering Rotor Dynamics and Balance (An Introduction to Lateral Critical and Train Torsional Analysis and Rotor Balancing)*

API Recommended Practice 686, *Machinery Installation and Installation Design*

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

ABMA 8.2, *Ball and Roller Bearing Mounting Accessories—Inch Design*

ABMA 9, *Load Ratings and Fatigue Life for Ball Bearings*

ABMA 11, *Load Ratings and Fatigue Life for Roller Bearings*

ABMA 20, *Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types—Metric Design*

AGMA 9002–B04 [2], *Bores and Keyways for Flexible Couplings (Inch Series)*

AISI [3], *Material Properties of Stainless Steel*

ANSI B16.11 [4], *Forged Fittings, Socket-welding and Threaded*

ANSI S12.54, *Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Engineering Method in an Essentially Free Field Over A Reflecting Plane*

ANSI B106.1M, *Design of Transmission Shafting*

---

1 American Brush Manufacturers Association, 2111 West Plum Street, Suite 274, Aurora, Illinois 60506, www.abma.org.
2 American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314, www.agma.org.
3 American Iron and Steel Institute, 1540 Connecticut Avenue, N.W., Suite 705, Washington, D.C. 20036, www.steel.org.
4 American National Standards Institute, 25 West 43rd Street, 4th floor, New York, New York 10036, www.ansi.org.

ASME *Boiler and Pressure Vessel Code* [5], Section V—*Nondestructive Examination*; Section VIII—*Rules for Construction of Pressure Vessels*; and Section IX—*Welding and Brazing Qualifications*

ASME B1.1, *Unified Inch Screw Threads (UN and UNR Thread Form)*

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

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

ASME B16.2, *Metallic Gaskets for Pipe Flanges—Ring-joint, Spiral-wound, and Jacketed*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

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

ASME B31.3, *Process Piping*

ASME B36.10M, *Welded and Seamless Wrought Steel Pipe*

ASTM A278 [6], *Standard Specification for Gray Iron Castings for Pressure-containing Parts for Temperatures Up to 650 °F (350 °C)*

ASTM A345, *Standard Specification for Flat-rolled Electrical Steels for Magnetic Applications*

ASTM A395, *Standard Specification for Ferritic Ductile Iron Pressure-retaining Castings for Use at Elevated Temperatures*

ASTM A469, *Standard Specification for Vacuum-Treated Steel Forgings for Generator Rotors*

ASTM A515, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

ASTM A536, *Standard Specification for Ductile Iron Castings*

ASTM A668, *Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use*

ASTM E94, *Standard Guide for Radiographic Testing*

ASTM E125, *Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings*

ASTM E142-92, *Method for Controlling Quality of Radiographic Testing* (withdrawn 2000)

ASTM E709, *Standard Guide for Magnetic Particle Examination*

ASTM D1868, *Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems*

AWS D1.1 [7], *Structural Welding Code—Steel*

---

5 ASME International, 3 Park Avenue, New York, New York 10016, www.asme.org.
6 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
7 American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126, www.aws.org.

CENELEC EN10250 [8], *Open Die Steel Forgings for General Engineering Purposes*, Part 1—*General Requirements*

IEC 60034-1[9], *Rotating Electrical Machines*, Part 1—*Rating and Performance*

IEC 60034-2, *Rotating Electrical Machines*, Part 2—*Methods for Determining Losses and Efficiency or Rotating Electrical Machinery from Tests [Excluding Machines for Traction Vehicles]*

IEC 60034-4, *Rotating Electrical Machines*, Part 4—*Methods of Determining Synchronous Machine Quantities from Tests*

IEC 60034-5, *Rotating Electrical Machines*, Part 5—*Degrees of Protection Provided by the Integral Design of Rotating Electrical Machines (IP Code)—Classification*

IEC 60034-6, *Rotating Electrical Machines*, Part 6—*Methods of Cooling (IC Code)*

IEC 60034-8, *Rotating Electrical Machines*, Part 8—*Terminal Markings and Direction of Rotation*

IEC 60034-15, Rotating Electrical Machines, Part 15—*Impulse Voltage Withstand Levels Of Rotating A.C. Machines With Form-wound Stator Coils*

IEC 60034-18, *Rotating Electrical Machines*, Part 18—*Functional Evaluation of Insulation Systems*

IEC TS 60034-27, *Rotating Electrical Machines*, Part 27—*Off-Line Partial Discharge Measurements on the Stator Winding Insulation of Rotating Electrical Machines*

IEC 60038, *IEC Standard Voltages*

IEC 60072, *Dimensions and Output Series for Rotating Electrical Machines*

IEC 60079, *Electrical Apparatus for Explosive Gas Atmospheres*

IEC 60270, *High Voltage Test Techniques—Partial Discharge Measurements*

IEC 60404-1-1, *Magnetic Materials—Classification—Surface Insulations of Electrical Steel Sheet, Strip and Laminations*

IEC 60894, *Guide for Test Procedures for the Measurement of Loss Tangent on Coils and Bars for Machine Windings*

IEEE C37.010 [10], *Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*

IEEE C50.13, *Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above*

IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

IEEE 95, *Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage*

IEEE 100, *The Authoritative Dictionary of IEEE Standard Terms*

[8] European Committee for Electrotechnical Standardization, 35 Rue de Stassartstraat, B-1050 Brussels, Belgium, www.cenelec.eu/Cenelec/Homepage.htm.

[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.

IEEE 115, *Test Procedures for Synchronous Machines*

IEEE 286, *Measurement of Power Factor Tip-up of Electric Machinery Stator Coil Insulation*

IEEE 303, *Recommended Practice for Auxiliary Devices for Rotating Electrical Machines in Class I, Division 2 and Zone 2 Locations*

IEEE 421.1, *Standard Definitions for Excitation Systems for Synchronous Machines*

IEEE 421.2, *Guide for Identification Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems*

IEEE 421.3, *Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines*

IEEE 429, *Recommended Practice for Thermal Evaluation of Sealed Insulation Systems for AC Electric Machinery Employing Form-wound Preinsulated Stator Coils for Machines Rated 6900 V and Below*

IEEE 522, G*uide for Testing Turn Insulation on Form-wound Stator Coils for Alternating-current Electric Machines*

IEEE 841, *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)*

IEEE 1349, *Guide for the Application of Electric Motors in Class 1, Division 2 Hazardous (Classified) Locations*

ISO 7 [11], *Pipe Threads (Pressure Type)*

ISO 15 (ISO/DIS 15), *Rolling Bearings—Radial Bearings—Boundary Dimensions, General Plan*

ISO 68 (ISO/DIS 68), *ISO General Purpose Screw Threads*

ISO 76, *Rolling Bearings—Static Load Ratings*

ISO 228-1, *Pipe Threads Where Pressure-tight Joints are not Made on the Threads*, Part 1—*Dimensions, Tolerances and Designation*

ISO 261, *ISO General Purpose Metric Screw Threads—General Plan*

ISO 281, *Rolling Bearings—Dynamic Load Ratings and Rating Life*, Part 1—*Calculation Methods*

ISO 286-1, *ISO System of Limits and Fits—Bases of Tolerances, Deviations and Fits*

ISO 492, *Rolling Bearings—Radial Bearings—Tolerances*

ISO 773 (ISO/R 773), *Rectangular or Square Parallel Keys and Their Corresponding Keyways (Dimensions In Millimetres)*

ISO 774 (ISO/R 774), *Taper Keys with or without Gib Head and Their Corresponding Keyways (Dimensions In Millimeters)*

ISO 775 (ISO/R 775), *Cylindrical and $^1/_{10}$ Conical Shaft Ends*

---

[11] International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

ISO 1027, *Radiographic Image Quality Indicators for Non-Destructive Testing—Principles and Identification*

ISO 1940/1, *Mechanical Vibration—Balance Quality Requirements for Rotors in a Constant (Rigid) State*, Part 1—*Specification and Verification of Balance Tolerances*

ISO 2229, *Equipment for the Petroleum and Natural Gas Industries*

ISO 3448, *Industrial Liquid Lubricants-ISO Viscosity Classification*

ISO 3452, *Non-Destructive Testing—Penetrant Inspection—General Principles*

ISO 3453, *Non-Destructive Testing—Liquid Penetrant*

ISO 3506, *Mechanical Properties of Corrosion Resistant Stainless-steel Fateners*

ISO 3744, *Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Engineering Method in an Essentially Free Field over a Reflecting Plane*

ISO 5579, *Non-destructive Testing—Radiographic Examination Of Metallic Materials By X- and Gamma-rays—Basic Rules*

ISO 5753, *Rolling Bearings—Radial Internal Clearance*

ISO 7005, *Metallic Flanges*

ISO 7483, *Dimensions of Gaskets for Use with Flanges to ISO 7005*

ISO 8501, *Preparation of Steel Substrates Before Application of Paints and Related Products—Visual Assessment of Surface Cleanliness*

ISO 9013, *Thermal Cutting—Classification of Thermal Cuts—Geometrical Product Specification and Quality Tolerances*

ISO 9328, *Steel Plates and Strips for Pressure Purposes—Technical Delivery Conditions*

ISO 9691, *Rubber—Recommendations for the Workmanship of Pipe Joint Rings—Description and Classification of Imperfections*

ISO 10438, *Petroleum, Petrochemical and Natural Gas Industries—Lubrication, Shaft-sealing and Control-oil Systems and Auxiliaries*

ISO 10721-1, *Steel Structure*, Part 1—*Materials and Design*

ISO 17025, *General Requirements for Competence of Calibration and Test Labs*

NEMA MG1 [12], *Motors and Generators*

NFPA 70 [13], *National Electrical Code*

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*

---

[12] National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209, www.nema.org.
[13] National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

NFPA 497, *Classification of Flammable Liquids, Gases, Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

SSPC SP6 [14], *Commercial Blast Cleaning*

TEMA [15], *Standards of the Tubular Exchanger Manufacturers Association*

2 Basic Design

2.1 General

2.1.1 The equipment (including auxiliaries) covered by this standard shall be suitable for the specified operating conditions and shall be designed and constructed for a minimum service life of 25 years and at least 5 years of uninterrupted continuous operation. It is recognized that this is a design criterion and that uninterrupted operation for this period of time involves factors beyond the vendor’s control.

● **2.1.2** Machines shall be designed for continuous operation and long periods of inactivity in an atmosphere that is made corrosive by traces of chemicals normally present in a petroleum processing facility. This environment may also include high humidity, storms, salt-laden air, insects, plant life, fungus, and animals. Machines shall be suitable for operation, periods of idleness, storage, and handling at the ambient temperatures listed under “Site Data” on the data sheets (see Annex A or Annex B). If additional considerations are necessary in the proposal, the purchaser shall specify them.

2.1.3 Unless otherwise specified, the A weighted maximum sound pressure level of the motor shall not exceed 85 dBA at any location at a reference distance of 1 m (3 ft) with the motor operating at no load, full voltage, rated frequency, and sinusoidal power. The measuring and reporting of sound pressure level data shall be in accordance with 4.3.5.1.1 g.

NOTE Some ASDs may cause increased motor sound levels due to increased operating speed (if operated above line frequency), excitation of mechanical resonances, magnetic noise caused by harmonics, etc. Purchaser should address these issues with the ASD and motor suppliers and reach agreement on resolution.

♦ **2.1.4** When specified, a mutually agreed upon sound level shall be measured while the motor is being driven by the contract ASD, or one that gives a similar waveform. The supply frequency shall be mutually decided by the purchaser and vendor.

● ♦ **2.1.5** All equipment shall be designed to run safely at the overspeed and duration specified in NEMA MG1 Part 21, Part 32, IEC 60034-1, or to the specified trip speed (including overshoot) of the connected equipment, whichever is greater. For machines driven by ASDs, the overspeed capability shall be mutually decided by the purchaser and vendor.

2.1.6 The arrangement of the equipment, including number of bearings, terminal housings, conduit, piping, and auxiliaries, (including the rotating elements of the exciter, the field discharge resistor, and synchronizing controls as applicable) shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for installation, operation, and maintenance.

2.1.7 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) easily accessible for operation, maintenance, and thorough cleaning;

---

[14] The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.
[15] Tubular Exchanger Manufacturers Association, 25 North Broadway, Tarrytown, New York 10591, www.tema.org.

c) installation in a neat and orderly arrangement adapted to the contour of the machine without obstructing access openings;

d) elimination of air pockets and traps;

e) complete drainage through low points without disassembly of piping; and

f) provision for easy removal of covers for maintenance and inspection.

• **2.1.8** The machine and all of its auxiliary devices shall be suitable for the area classification specified by the purchaser on the data sheets. Auxiliary devices shall be listed or certified where required in accordance with the area classification system specified, i.e. NFPA 70, Articles 500, 501, 502 and 505 (Class, Group, Division or Zone, and Temperature Code), or IEC 60079-10 (Zone, Class, Group, and Temperature Code) and specified local codes.

NOTE See IEEE 303, IEEE 1349, and IEC 60079 for additional guidance and information on application of motors and accessories in hazardous locations.

2.1.9 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 meet the requirements of IP 55 as a minimum to reduce contamination by moisture, dust, and other foreign matter.

2.1.10 All equipment shall be designed to facilitate field inspection and maintenance. Major parts such as frame components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly. This shall be accomplished by the use of shouldering, cylindrical dowels or keys. Easily removable covers shall be provided for maintenance and inspection of coil end turns, the exciter, synchronizing controls and rotor windings as applicable.

2.1.11 Every effort shall be made to avoid requirements for special tools. However, when tools and fixtures not commercially available are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply. For multiple-unit installations, the purchaser and vendor shall mutually agree on the requirements for quantities of special tools and fixtures.

2.1.12 When special tools are provided, they shall be packaged in separate, rugged boxes or containers and marked as “special tools for (tag/item number).” Each tool shall be tagged to indicate its intended use.

2.1.13 The equipment (machine and auxiliary equipment) shall perform on the test stand and on their permanent foundation within the specified acceptance criteria. The performance on the permanent foundation may differ from performance on the test stand. (See 2.4.6.) After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

2.2 Electrical Design

2.2.1 Rating and Voltage

• **2.2.1.1** Unless otherwise agreed by the purchaser, either NEMA or IEC standard ratings shall be used. If the required rating falls between two listed ratings, the larger listed rating shall be selected. For generators, standard kilovolt-ampere and kilowatt ratings shall be selected.

2.2.1.2 Unless otherwise specified, machines shall be rated for the bus voltage.

For 50 Hz supply systems, two different voltage systems are standardized in IEC 60038. Table 2 is widely used in countries following British standards. Table 3 is used for 50 Hz systems in general.

NOTE 1 Either one of the 50 Hz voltage series may be used as listed in IEC 60038.

Table 1—Typical Voltage Ratings for 3-phase 60 Hertz (Hz) Systems

Horsepower or kVA	Machine Voltage	Bus Voltage
500–4,000	2,400	2,400
500–7,000	4,160	4,160
1,000–12,000	6,900	6,900
3,500–Above	13,800	13,800

Table 2—Typical Voltage Ratings for 3-phase 50 Hz Systems

kW	Machine Voltage	Bus Voltage
500 – 4,000	3,300	3,300
500 – 12,000	6,600	6,600
4,000 – Above	11,000	11,000

Table 3—Voltage Ratings for 3-phase 50 Hz Systems

kW	Machine Voltage	Bus Voltage
500 – 4,000	3,000	3,000
500 – 12,000	6,000	6,000
4,000 – Above	10,000	10,000

NOTE 2 Other voltages may be necessary to conform with site specific voltages not listed above.

2.2.1.2.1 Unless otherwise specified, the machine shall operate with a maximum voltage variation of ± 10 % and a maximum frequency variation of ± 5 % and a total combined variation not to exceed ± 10 %, per NEMA MG1 Part 21, or IEC-60034.

♦ **2.2.1.2.2** For motors operating only on ASDs the voltage and frequency ratings shall be mutually agreed upon by the purchaser and vendor.

NOTE In general, ASD voltage harmonics and voltage/frequency ratio should match motor design parameters (voltage & flux). The resultant maximum rms voltage should not exceed the motor voltage rating nor should motor rms current exceed the continuous sinusoidal nameplate rating. The motor manufacturer should be informed by the purchaser of any deviations and appropriate design accommodations should be mutually agreed between purchaser and manufacturer.

2.2.1.3 Machines shall be capable of continuous operation at rated load (1.0 service factor) and temperature rise in accordance with 2.3.1.1 when operated, both mechanically and electrically, at rated power, power factor, voltage, and frequency. In applications that require an overload capacity, a higher rating should be used to avoid exceeding the temperature rises for the class of insulation used and to provide adequate torque capacity.

Maximum momentary overload capability for synchronous generators shall be per NEMA MG1 Part 32 or IEC 60034-1.

2.2.2 Stator Windings

2.2.2.1 Coil ends shall be braced to prevent insulation cracking and fatigue as a result of motion during operation and starting. The stator windings shall be braced to withstand an external line-line-ground short circuit at full load and 110 % of rated voltage. Motor windings shall withstand the starting duties specified in 2.2.5.

2.2.2.2 Machines 750 kW (1000 HP) and larger, or when specified, shall have both ends of each stator-phase winding brought out to a terminal box (see 3.1.8).

2.2.3 Load Requirements

2.2.3.1 Unless otherwise specified, the load torque characteristics and total load inertia referred to the motor shaft shall be in accordance with NEMA MG 1 Part 21.

• **2.2.3.2** Should the loads have characteristics other than those listed in NEMA MG1 Part 21, the purchaser shall fully specify the load characteristics of the driven equipment. These shall include:

a) the speed torque characteristics of the load under the most stringent starting conditions; and

b) the speed torque characteristics of the load during reaccelerating conditions when reacceleration following bus transfer is specified; and

NOTE Electrical machines are capable of developing transient current and torque considerably in excess of rated values when exposed to an out of phase bus transfer or momentary voltage interruption and reclosing. The magnitude of this transient torque may be many times rated torque and is a function of the machine design, operating conditions, switching time, rotating machine inertias and torsional spring constants, number of motors on the bus, etc. See NEMA MG 1 Part 21 for bus transfer or reclosing information.

c) the total load inertia J (Wk^2) referred to the motor shaft speed, where W is the rotating weight and k is the radius of gyration. This total load inertia shall include all loads connected to the motor shaft, such as couplings, gearbox and driven equipment.

NOTE To obtain Wk^2 [lb-ft^2] multiply J [kg-m^2] by 23.73

$$J = 0.25GD^2$$

$$D = 2R$$

where;

J is the polar mass moment of inertia (kg-m^2);

G is the rotating mass (kg);

D is the diameter;

R is the radius of inertia (m).

2.2.4 Starting Conditions

2.2.4.1 Unless otherwise specified, the motor shall be designed to start and accelerate the connected load to running speed with 80 % of rated voltage at the motor terminals.

• **2.2.4.2** When specified, the requirements for starting capability, speed-torque, and acceleration time shall be determined with the following information, as applicable, furnished by the purchaser:

a) starting method (e.g. captive transformer, reactor, auto-transformer, solid state, etc.);

b) the minimum allowable voltage at the motor terminals under specified locked rotor current; or

c) the minimum available system short circuit kVA and X/R ratio including the base voltage and the minimum motor terminal voltage during starting in % of rated motor voltage.

2.2.4.3 When the motor speed-torque curve at the conditions specified in 2.2.4.1 or 2.2.4.2 is plotted over the load speed torque curve, the motor developed torque shall exceed the load torque by a minimum of 10 % (motor rated torque as the base) at all locations throughout the speed range up to the motor pull-in torque point.

NOTE Some ASDs may limit motor accelerating torque at reduced speeds due to insufficient flux (Volts/Hertz) levels or limitations in the drive's momentary current capacity and excitation system. If a special motor design is required to compensate for such ASDs, the purchaser should so advise the motor supplier and appropriate design changes agreed upon.

2.2.4.4 For certain machine designs, high inertia loads, or power system limitations, the requirements provided in clauses 2.2.3.1, 2.2.4.1, and 2.2.6.1 b may not be practical. In these cases, the motor starting characteristics shall be jointly developed between the purchaser and vendor.

2.2.5 Starting Capabilities

2.2.5.1 Unless otherwise specified, the machine shall be designed for a minimum of 5000 full voltage starts. Fixed-speed motors shall also have the starting capabilities in Table 4.

NOTE Typical petroleum process plant operations are such that a motor will have a period of initial use of about 2 months for pump and compressor run-in and initial plant operations, during which time the maximum starting capability may be used. A need for maximum capability may also occur during subsequent start-ups. Between these start-up periods, there are usually longer periods of continuous running.

2.2.5.2 Starting capabilities for motors different from those shown in Table 4 shall be jointly developed between the purchaser and the vendor (see Note 2 following Table 4).

Table 4—Starting Capabilities

Capablility	Number of Starts
Consecutive starts with the motor coasting to rest between starts	2
Consecutive starts with the motor coasting to rest and remaining idle for 20 minutes	3
Evenly spaced starts in first hour before continuous running	3

NOTE 1 The first start is a cold start.

NOTE 2 The starting capabilities for synchronous motors are normally a result of an individual design for the specific load characteristics of the driven equipment and the electrical power system for the most stringent conditions. Therefore, it may be necessary to reduce the number of starts by one for large, high inertia drives like gear-type turbocompressors etc. For pumps and other low inertia applications the number of starts may be increased to allow maximum starting flexibility for the operation.

2.2.5.3 The motor manufacturer shall provide adequate motor thermal capacity data for calculating restart capabilities under the following conditions:

a) subsequent to a recent start sequence with the motor running; and

b) subsequent to a recent start sequence with the motor stopped.

The information shall include adequate data for the setting of the motor thermal time constant in protective devices.

2.2.5.4 The minimum safe stall (locked rotor) time shall be the greater of 150 % of, or 5 seconds more than the time required to accelerate the actual driven load with the voltage values specified under 2.2.4.1 or 2.2.4.2. If these conditions cannot be met, the vendor shall notify the purchaser and recommend an alternative or a suitable protection scheme. The method of safe stall time calculation and the limits shall be described with the proposal.

2.2.6 Performance

2.2.6.1 With their rated voltage and frequency applied, machines shall, as a minimum, operate with the characteristics listed below. This does not apply to units started by, or operated on ASDs. Where these limits will have an adverse effect on other characteristics, particularly efficiency, the vendor shall state the effect and recommend preferred values.

a) The maximum locked-rotor current shall not exceed 500 % of the full-load current.

b) The minimum locked-rotor, pull-in, and pull-out torques shall not be less than the values listed in NEMA MG 1 Part 21 or IEC 60034-1.

• c) Current pulsations under the actual operating conditions shall be within the limits stated within API 618 or NEMA MG 1 Part 21, as specified.

♦ **2.2.6.2** When motor supply is from an ASD only (no bypass operation), the characteristics may be different from those listed in 2.2.6.1 and shall be determined to optimize performance on the ASD

NOTE 1 Use of motors on ASDs may lead to higher rotor and stator temperatures due to harmonic currents, which should be assessed for application in Division 2 and Zone 2 applications. In addition, the “displaced neutral” effect of some drive topologies may lead to the shaft being at an elevated voltage to ground. The possibility of discharge and consequent ignition should be considered.

NOTE 2 Torsional oscillations may be caused by the drive harmonics, and a torsional study should be performed.

NOTE 3 Damage to the motor and drive may be caused by improper application of system capacitance. Also possible resonances may be caused by application of surge capacitors, which are not recommended for adjustable speed applications.

2.3 Insulation Systems

2.3.1 General Requirements

Class B temperature limits apply to the armature, field, and exciter windings.

2.3.1.1 The main stator winding shall have an epoxy base, vacuum pressure impregnated, nonhygroscopic insulation system, including the stator lead connections to the windings. The insulation system shall be capable of withstanding a sealed winding conformance test in accordance with NEMA MG 1 Part 20. When bus bars are used, they shall be insulated.

As a minimum, the insulation system shall meet the criteria for Class F insulation; however, the allowable temperature rise above ambient, 40 °C (104 °F), shall not exceed that listed for Class B insulation in NEMA MG 1-21, IEEE C50.13 or IEC 60034-1 limits as applicable. For ambient temperatures above 40 °C the allowable temperature rise shall be reduced accordingly so as to not exceed the total temperature limits (ambient, rise and hot spot) for Class B insulation. For windings operating at voltages of 6 kV (line-line) or greater, the use of corona suppressant materials is required. Strand insulation shall adhere tightly to the strand. Turn and ground wall insulation shall be resistant to the effects of corona. The integrity of strand and turn insulation shall be maintained during forming, winding and VPI treatment.

♦ **2.3.1.2** Motors for use on ASDs shall have temperature rises in accordance with 2.3.1.1 throughout the speed range when applied to the specified ASD and load. If the ASD output current harmonics are significant, purchaser shall provide the motor supplier with full harmonic data.

NOTE Motor should be designed for the full range of speed and torque requirements of the application to avoid excessive winding temperature due to insufficient cooling or excessive torque levels. Purchaser should supply motor vendor with these parameters.

♦ **2.3.1.2.1** If the ASD has an output waveform with repetitive high amplitude voltage spikes, the purchaser shall advise motor manufacturer so that the insulation system can be modified accordingly to avoid premature insulation breakdown.

♦ **2.3.1.2.2** Motors used on ASD designs which impose common mode voltage shall be provided with motor ground insulation capable of continuous operation with the resulting level of voltage at the motor terminals. The purchaser shall supply the motor supplier with the value of common mode voltage that will be imposed.

2.3.1.3 For multi-turn stator windings, additional turn insulation shall be used as required to maintain the integrity of turn insulation in the noses or other areas of coil deformation. The insulation system shall be capable of withstanding the surge test specified in 4.3.4.2. Special provisions shall be made to seal the leads where they exit the coil.

2.3.1.4 Field coil turn insulation shall be maintained during forming, winding, and curing. Rotor coils made from rectangular wire or edgewound strips shall be adequately insulated and securely braced. Additional ground insulation and blocking shall be used as required to maintain the integrity of insulation. To improve the cooling effect, individual turns of the windings may project on particular sides or all around the pole to form cooling fins. Adequate creepage paths, distances and clearances shall be provided on all current-carrying conductors. The complete rotor winding system shall withstand the mechanical and electrical stresses that occur during starting and normal operating, surge, overspeed, and short-circuit conditions, as well as during shutdown and all tests specified. The rotor insulation system for motors shall be protected by shorting out the rotor through the exciter converter and by-pass thyristors or by a field discharge resistor.

The insulation on field windings shall maintain its integrity while withstanding the centrifugal forces and thermal stresses at Class F temperature without damage. Special attention shall be given to adequate support of both coil-to-coil connections and coil-to-main-field-lead connections.

2.3.1.5 The exciter armature and exciter field insulation shall be Class F, using a highly moisture-and chemical resistant, cured material. The conductor strands shall be individually insulated by an enamel coating, a glass weave, or a combination of these that is saturated with varnish to provide turn-to-turn insulation.

• **2.3.1.6** When specified, the exciter armature and field windings shall have a sealed insulation system, as defined by NEMA MG 1 Part 1.

2.3.1.7 The total insulation system shall be impervious to the operating conditions specified in 2.1.2. Sheared exposed edges of insulation parts shall be sealed. All insulation, including lead insulation, shall be impervious to attack by the lubricating oil specified.

2.3.1.8 All stator insulation systems shall be service proven and shall have been subjected to thermal evaluation in accordance with IEEE 429 or IEC 60034-18.

♦ **2.3.1.9** In cases where the motor power is to be supplied from an ASD, the insulation system shall be selected to withstand the applied voltage waveform, which may include a displaced neutral or high rates of change of terminal voltage.

2.3.1.10 The entire stator winding insulation system, including winding connections and terminal leads, shall be tightly secured to prevent insulation cracking and fatigue as a result of motion and vibrations during starting, operation, and electrical transient conditions which produce electromechanical forces in the stator windings. The windings shall withstand electromagnetic and mechanical forces under normal operating conditions, the starting requirements specified in 2.2.4, and the forces associated with phase-to-phase and 3-phase short circuits with 110 % of rated voltage.

• **2.3.1.11** Conductors between the windings and main terminals shall be insulated and be separated from ground planes so that the effects of partial discharge are minimized. The machine leads shall have Class F insulation and be sized for a minimum of 125 % of rated current at Class B temperature rise. Conductors shall be braced and protected from chafing against the motor frame and terminal box. If electrical grade fiberglass is used for this purpose, it shall be vacuum pressure impregnated so as to be made nonhygroscopic. When specified, machines rated 6 kV and above shall not use cable between the stator winding to the main terminal box connection.

2.3.1.12 Magnetic slot wedges shall not be used.

2.4 Mechanical Design

2.4.1 Enclosures

2.4.1.1 General Requirements

The following general requirements apply to enclosures.

a) Enclosure parts shall be made of cast or nodular iron, cast steel, or steel plate. Purchaser-approved fiber-reinforced materials may be used for parts such as covers or nonsupportive enclosure sections. All enclosure parts shall have a minimum rigidity equivalent to that of sheet steel with a nominal thickness of 3.0 mm ($^1/_8$ in.). Machines utilizing the foundation as part of the enclosure, such as large diameter machines, shall be identified in the proposal.

b) Air deflectors shall be made of corrosion-resistant material or shall have corrosion-resistant plating or treatment.

• c) All the enclosure's bolts, studs, and other fastening devices up through M12 ($^1/_2$ in.) size shall be AISI 300 series or ISO 3506 stainless steel. Where the motor will be installed offshore on a production platform or similar marine installation, or when specified, AISI 316 material shall be supplied in lieu of the 300 series fasteners. Internal fastening devices shall use locknuts, lock washers, locking plates, or tie wires.

d) The risks due to possible circulating currents in the enclosure shall be considered for machines using multi-section enclosures installed in classified locations. Overheating or sparking due to possible circulating currents shall be avoided, where necessary, by bonding together the conducting components in a secure electrical and mechanical manner, or by the provision of adequate bonding straps between the motor housing components. The means shall be functional over the design life of the machine.

• e) When specified for totally enclosed air to air (TEACC), or totally enclosed water to air (TEWAC) type enclosures.

NOTE See IEEE 303, IEEE 1349, and IEC 60079 for information.

f) Unless otherwise specified, machines rated 6 kV and above shall have TEAAC or TEWAC enclosures (IP4x or IP5x, with IC4xx, IC6xx or IC8xx type cooling. See Table 5).

2.4.1.2 Machine Enclosures and Corresponding NEMA or IEC Specifications

• **2.4.1.2.1** Table 5 lists types of machine enclosures and the NEMA or IEC specifications to which they shall conform. The purchaser shall specify the type of enclosure on the data sheets. Enclosures shall also conform to the requirements of 2.4.1.2.2, 2.4.1.2.3 and 2.4.1.2.4.

2.4.1.2.2 Drip proof guarded (DPG), weather-protected Type I and weather-protected Type II enclosures, or the IEC equivalents shall meet the following criteria:

a) Ventilation openings shall be limited to a maximum size of 6.4 mm (1/4 in.) by design or by the use of metal screens in accordance with 2.4.10.5 and 3.5.1.

b) Weather-protected enclosures shall be constructed so that any accumulation of water will drain from the motor.

• c) When abrasive-dust conditions have been specified on the data sheets under "Site Data," electrical insulation shall be protected from the abrasive action of airborne particles. This protection shall be in addition to the VPI resin and the manufacturer's standard coating.

NOTE Drip proof or Weather Protected Type I (WPI) enclosures are not recommended for the operating conditions specified in 2.1.2 (that is outdoor operation without a protective shelter). Purchasers applying this degree of protection should expect reduced reliability (see 2.1.1 and Table 5).

Table 5—Machine Enclosures and Corresponding NEMA or IEC Specifications

Common Enclosure Type	Designation NEMA MG 1	Specifications NEMA MG 1	Degree of Protection [1] IP Code	Method of Cooling [2] IEC 60034-6
Drip proof guarded	DPG	1.25.5	IP22	IC01
Weather protected				
Type I	WP-I	1.25.8.1	IP23	IC01
Type II	WP-II	1.25.8.2	IPW24	IC01
Totally Enclosed				
Fan cooled	TEFC	1.26.2	IP44/54	IC411
Pipe ventilated	TEPV	1.26.4	IP44	IC31/37
Water/air cooled	TEWAC	1.26.7	IP44/54	IC81W
Air/air cooled	TEAAC	1.26.8	IP44/54	IC611 [3] IC616 [4]

1 IEC 60034, Part 5, NEMA MG 1, Section 5.
2 IEC 60034, Part 6, NEMA MG 1, Section 6.
3 Shaft Driven Secondary Fan.
4 Auxiliary Secondary Fan.

NOTE The designation used for degree of protection consists of the letters IP followed by two characteristic numerals signifying conformity with the conditions indicated in the tables. When it is required to indicate a degree of protection by only one characteristic numeral, the omitted numeral is replaced by the letter X. For example IPX5 or IP2X.

2.4.1.2.3 Totally enclosed machines (TEFC, TEPV, TEWAC and TEAAC) shall meet the following criteria:

a) Designs in which the stator laminations form a part of the enclosure are not acceptable.

b) Fan covers shall be made of metal having a minimum rigidity equivalent to that of steel plate with a nominal thickness of 3.0 mm (1/8 in.). Purchaser-approved fiber-reinforced materials may be used. The air intake opening shall be guarded by a grill or a metal screen fastened on the outside of the fan cover. Requirements for grills or metal screens are covered in 2.4.10.5.

c) Sheet metal covers or wrappers used to form air passages over the enclosure shall have a minimum rigidity equivalent to that of steel plate with a nominal thickness of 3.0 mm (1/8 in.).

d) Totally enclosed machines shall be equipped with a plugged, threaded drain connection located at the lowest point of the frame. This connection shall be shown on the outline drawing.

e) Requirements for heat exchanger tubes are in 2.4.10.8.

f) Where an enclosure make-up air intake is required for supplying pressurized air to the bearing seals, the intake shall be provided with filters suitable for the site data given on the data sheets.

2.4.1.2.4 Totally enclosed water-air-cooled (TEWAC) machines shall be designed for the following conditions.

• a) Cooling water systems shall be designed for the following conditions unless the vendor notifies the purchaser that conflict will arise affecting performance, size/cost and integrity of the cooler. The purchaser shall approve the final selection. Where specified, coolers shall be designed to operate with a water/glycol solution.

Velocity over heat exchange surfaces	≥ 1.5 m/s – 2.5 m/s	5 ft/s – 8 ft/s
Maximum allowable working pressure MAWP (Gauge)	7.0 bar	≥ 100 psig
Test pressure (1.5 MAWP)	≥ 10.5 bar	≥ 150 psig
Maximum pressure drop	1 bar	15 psig
Maximum inlet temperature	32 °C	90 °F
Maximum outlet temperature	49 °C	120 °F
Maximum temperature rise	17 K	30 °F
Minimum temperature rise	11 K	20 °F
Water side fouling factor	0.35m^{2}K/kW	0.002hr-ft^2-°F/Btu
Corrosion allowance for carbon steel shells	3 mm	$^1/_8$ in.

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 will approve the final selection.

• b) When specified, machines shall be provided with multiple coolers to allow one cooler to be removed from service without reducing the continuous operating capability.

• c) The location of the cooler, orientation of the water box inlet and outlet, materials, construction of the cooler, cleaning requirements, and means of leak detection shall be specified on the datasheets. Leak detectors shall be provided to sense tube leakage. For double tube coolers, these detectors shall sense inner tube leakage and when specified, outer tube leakage.

• d) Cooler designs shall be of the water-tube type (water in the tubes). U-tube construction is not permitted. The construction of the water box and header shall be such that leaking tubes can be plugged and all tubes are accessible for cleaning. When specified, coolers shall be of double-tube construction.

e) The machine's interior shall be baffled or otherwise constructed to prevent cooler-tube leakage from striking the windings.

f) The machine shall be constructed so that cooler leakage will collect and drain. In pressurized enclosures, a liquid seal shall be provided for drain holes.

• g) When specified, a flow-sensing device shall be provided for mounting in the water supply piping to each cooler.

• h) When specified, temperature sensors shall be provided to sense air temperature into and out of the coolers.

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

j) Requirements for heat exchanger tubes are in 2.4.10.8.

2.4.2 Frame And Mounting Plates

♦ **2.4.2.1** The frame of the completely assembled machine on its permanent foundation with the rotor installed and rotating, shall be free from structural resonance within 85 % to 115 % and 185 % to 215 % of the electric line frequency, 40 % to 60 % of the operating speed and the following frequency ranges:

$$N = nN_{op} \pm 0.15N_{op} \tag{1}$$

where

N is the frequency range, in Hz;

N_{op} is the operating speed frequency, in Hz;

n is equal to 1 and 2.

NOTE Transfer of vibration from surrounding equipment is avoided by proper layout of the foundation, which is the responsibility of the purchaser. After the machine is erected, the natural frequency of the foundation should not occur within 80 % to 120 % of 180 % to 220 % of running speed frequency or electric line frequency or between 40 % and 60 % of running speed frequency.

For machines operating at adjustable speed with an operating speed range where it may not be possible to avoid all machine frame or enclosure resonances, the purchaser and machine supplier shall agree on a strategy to avoid damage to the machine or drive train. The user may waive this requirement if the supplier can demonstrate that the vibration requirements of 4.3.3.13 are satisfied. Other strategies may include limiting speed range, blocking problematic frequency range(s), or adding stiffeners or damping means to the base/mounting arrangement.

● **2.4.2.2** The stress values used in the design of the frame shall not exceed the values given for that material in Section II of the ANSI/ASME Code at the maximum operating temperature. For cast materials, the factors specified in Section VIII, Division I, of the ASME Code or ISO 10721 shall be applied. The conditions evaluated shall include short circuits, out-of-phase synchronism, thrusts, handling, and specified seismic loading.

2.4.2.3 The frame, including the transition base if supplied with the machine, and the bearing supports shall be designed to have sufficient strength and rigidity to limit changes of alignment caused by the worst combination of torque reaction, conduit and piping stress, magnetic imbalance, and thermal distortion to 0.05 mm (0.002 in.) at the coupling flange (this is not to be confused with the normal repeatable thermal growth between ambient and operating temperatures).

2.4.2.4 Supports and the design of jackscrews shall be rigid enough to permit the machine to be moved by the use of the lateral and axial jackscrews.

2.4.2.5 Horizontal machines shall be equipped with vertical jackscrews appropriately located to facilitate alignment. If size and weight prohibit the use of jackscrews, other provisions shall be made for vertical jacking.

● **2.4.2.6** When specified, the machine shall be furnished with soleplates or a baseplate.

2.4.2.7 The term “mounting plate” refers to both baseplates and soleplates.

2.4.2.7.1 Mounting plates shall be equipped with vertical jackscrews to permit leveling of the mounting plates.

a) For baseplates, a minimum 16 mm (5/8 in.) diameter jackscrew hole shall be located a minimum of 100 mm (4 in.) from each anchor bolt hole along the same centerline as the anchor bolt holes.

b) For soleplates, a minimum of 4 jackscrew holes shall be supplied. These holes shall be designed for a minimum of 16 mm (5/8 in.) jackscrew and shall be located in each corner of the soleplate. In addition, for soleplates longer than 0.9 m (3 ft) two additional jackscrew holes shall be installed in the soleplate at midspan with their centerlines similar to the corner jackscrew holes. Sole plates 1.8 m (6 ft) and longer shall have a maximum span of 0.9 m (3 ft) between jackscrew holes on each side of the soleplate. All jackscrew holes shall be located a minimum of 100 mm (4 in.) from the anchor bolt holes.

c) Jackscrew holes shall be drilled and tapped a length equal to the diameter of the jackscrew. The soleplate shall be counterbored at the jackbolt hole locations to a diameter large enough to allow the use of a socket drive over the head of the jackscrew. The depth of the counterbore shall be equal to the thickness of the soleplate minus the diameter of the jackscrew.

2.4.2.7.2 To assist in machine positioning, the mounting plates shall be furnished with horizontal jackscrews (for machine movement in the horizontal plane) the same size as or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates so that they do not interfere with the installation or removal of the drive element and the installation or removal of shims used for alignment.

2.4.2.7.3 Mounting plate anchor bolts shall not be used to fasten the machine to the mounting plates.

2.4.2.7.4 To minimize grout stress cracking, mounting plates that are to be grouted shall have 50 mm (2 in.) radius on the outside corners (in the plan view). The bottom edges of the soleplate shall have a 25 mm (1 in.) 45 degree chamfer.

2.4.2.7.5 Mounting plates shall be designed to extend at least 25 mm (1 in.) beyond the outer sides of the machine feet.

2.4.2.7.6 The vendor of the mounting plates shall furnish AISI 300 series stainless steel shim packs at least 3.0 mm (1/8 in.) thick between the machine feet and the mounting plates. All shim packs shall straddle the hold-down bolts.

2.4.2.7.7 Anchor bolts shall be furnished by the purchaser.

2.4.2.7.8 Fasteners for attaching the components to the mounting plates and jackscrews for leveling the soleplates shall be supplied by the vendor.

2.4.2.7.9 The horizontal and vertical jack bolts shall be M16 ISO 68 minimum diameter (5/8 in. with UNC threads) and having a round nosed end.

2.4.2.8 Frame mounting surfaces shall meet the following criteria:

a) They shall be machined to a finish of 6.3 μm (250 μin.) arithmetic average roughness (R_a) or better.

b) To prevent a soft foot, they shall be in the same horizontal plane within 125 μm (0.005 in.).

c) Each mounting surface shall be machined within a flatness of 40 μm per 1000 linear mm (0.0005 in. per linear ft) of mounting surface.

d) Different mounting planes shall be parallel to each other within 0.17 mm/m (.002 in./ft).

e) In a horizontal machine the mounting planes shall be parallel to a horizontal plane through the bearing centerline within 0.17 mm/m (0.002 in./ft).

f) The upper machined or spot faced surface shall be parallel to the mounting surface.

g) Hold down bolt holes shall be drilled perpendicular to the mounting surface or surfaces, and be drilled 13 mm (0.5 in.) larger in diameter than the hold down bolt. Due to the extra large clearance hole, properly designed load bearing washers shall be provided. The mounting faces shall be parallel to the feet mounting surfaces and large enough so that the load bearing washers can still contact the mounting faces when the machine is aligned in its extreme position where a bolt is touching one side of its clearance hole.

2.4.2.9 The mounting surface on a vertical machine shall be machined perpendicular to the machine's centerline, and this surface shall not deviate from that perpendicular plane by more than 0.17 mm/m (0.002 in./ft).

2.4.2.10 The frame support or supports shall be provided with two pilot holes for dowels. The holes shall be as near vertical as is possible and shall be located to provide adequate space for field drilling and reaming (if required), and placement of dowels. Unless otherwise specified, only the supports or mounting feet on the drive end of horizontal machines shall be doweled. Vertical machines shall have a rabbitted fit to the base and two dowels.

2.4.2.11 Alignment dowels or rabbitted fits shall be provided to facilitate disassembly and reassembly of end bells or plates, bearing-housing mounting plates, and bearing housings. When jackscrews are used as a means of parting contacting faces, one of the faces shall be counterbored or recessed to prevent a leaking joint or an improper fit caused by marring of the face.

2.4.2.12 When the vendor provides tapered dowel pins, the top end of the dowel shall have an undercut shank threaded to the nominal diameter nearest the dowel's outside diameter. The first two threads shall be machined off, and the shank shall be beveled to prevent damage when the pin is driven. A hex nut shall be provided with each pin.

• **2.4.2.13** Lifting lugs, through holes, or eyebolts shall be provided for lifting major components and the assembled machine. Any special mechanisms for lifting major components and the assembled machine shall be supplied in the quantities shown on the data sheets.

2.4.2.14 All fabricated welded structural steel shall be post-weld stress relieved. This does not apply to sheet metal components. If post-weld stress relieving is not possible, the vendor shall advise methods to keep the frame free of unacceptable internal stresses.

• **2.4.2.15** When specified, an axial stator shift shall be provided (see 1.5.17).

2.4.3 Frame Connections

2.4.3.1 Unless otherwise specified, inlet and outlet connections for field piping, including those for air, lubrication, cooling medium, instrumentation, conduit, bus ducting, and drains, shall have the vendor's standard orientation and size, except that sizes of 1 $^1/_4$, 2 $^1/_2$, 3 $^1/_2$, 5, 7, and 9 in. shall not be used.

2.4.3.2 Tapped openings not connected to piping shall be plugged with solid round head steel plugs furnished in accordance with ANSI B16.11 or ISO 2229. Plugs that may later require removal shall be of a compatible, corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs and threading are not permitted.

2.4.3.3 Bolting and threading shall be furnished as specified in 2.4.3.3.1 through 2.4.3.3.3.

2.4.3.3.1 The details of threading shall conform to ASME B1.1 or ISO 68 and ISO 261.

2.4.3.3.2 Hexagonal head bolts or cap screws shall be supplied on all frame connections except oil piping, unless the purchaser specifically approves studs.

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

2.4.3.4 Openings for piping connections, except bearing oil inlet lines, shall be at least 20 mm ($^3/_4$ in.) nominal pipe size. Oil inlet lines shall be not less than 12 mm ($^1/_2$ in.). All pipe connections shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings in sizes through 40 mm (1 $^1/_2$ in.) nominal pipe size, shall be fitted in accordance with the requirements below.

A pipe nipple, preferably not more than 150 mm (6 in.) long, shall be screwed into the threaded opening.

Pipe nipples shall be a minimum of Schedule 80 ASME B36.10.

Tapped openings and bosses for pipe threads shall conform to ASME B16.5.

2.4.3.5 Piping flanges shall conform to ASME B16.2 or ISO 7483 or ISO 9691 or B16.5 as applicable, except as specified in 2.4.3.5.1 and 2.4.3.5.2.

2.4.3.5.1 Cast iron flanges shall be flat faced and shall have a minimum thickness of Class 250 for sizes 200 mm (8 in.) and smaller.

2.4.3.5.2 Flat-faced flanges with full raised-face thickness are acceptable on frames other than cast iron.

2.4.3.6 Machined and studded connections shall conform to the facing and drilling requirements of ASME B16.1 or B16.5. Studs and nuts shall be furnished installed.

2.4.3.7 Tapped openings and bosses for pipe threads shall conform to ASME B16.5. Pipe threads shall be taper threads conforming to ASME B1.20.1.

2.4.3.8 Openings for duct connections shall be flanged and bolted. Connection facings shall be adequate to prevent leakage with proper gaskets and bolts. Unless otherwise specified, gaskets and bolts shall be provided by the vendor.

2.4.3.9 Studded connections shall be furnished with studs installed. Blind stud holes in casings shall be drilled deep enough to allow a preferred tap depth, of 1 $^1/_2$ times the major diameter of the stud. The first 1 $^1/_2$ threads at both ends of each stud shall be removed.

• **2.4.4 External Forces And Moments**

Frames and housings are generally designed to accept small external forces and moments from duct, conduit, and piping connections. If the auxiliary equipment (that is, ducting, coolers, silencers, and filters) is not supplied by the vendor, it is the purchaser's responsibility to specify on the data sheets the external loads expected to be imposed on the enclosures from this equipment. The vendor shall design the frame to accept the specified loads.

2.4.5 Rotating Element

2.4.5.1 General

• **2.4.5.1.1** The rotating element shall be designed and constructed to withstand the starting duties specified in 2.2.4, 2.2.5, and 2.2.6 with a minimum fatigue life of 5000 full-voltage starts or as specified by the purchaser.

2.4.5.1.2 Shafts shall comply with the following.

a) Suitable fillets shall be provided at all changes in diameter and in keyways. Stress concentration factor calculations shall be performed to insure that the shaft stresses have a fatigue life as required in 2.1.1 and 2.2.5.

b) Welded shaft and bar shaft/spider construction is not allowed for two pole machines.

c) Shaft-straightening techniques are not permitted during or after fabrication of the rotor.

2.4.5.1.3 Heat-treated forged steel shafts shall be used for machines having any of the following characteristics:

a) finished journal diameter 100 mm (4 in.) and larger;

b) two and four pole solid cylindrical rotor machines;

c) operation above the first lateral critical speed;

d) driving a reciprocating load or driven by a reciprocating prime mover; and

e) using tapered hydraulic fit couplings.

Hot-rolled shafts may be used for all other machines if the vendor can demonstrate a minimum of two years successful operating experience with this design in that application.

2.4.5.1.4 Heat-treated forged steel shafts shall be as a minimum AISI 4000 series and comply with ASTM A668 or the equivalent in EN10250. Any inclusions in the forging shall be limited to a value that will not have an adverse impact on the finished shaft. Two and four pole solid cylindrical rotor shafts shall comply with ASTM A469 with suitable grade/class for the application.

2.4.5.1.5 For motors driving reciprocating loads and generators driven by a reciprocating type prime mover, a complete torsional analysis shall be performed, in accordance with 2.4.6.2.7, by the party specified by the purchaser. This analysis shall include all operating conditions including transient starting, no load and full load. The stress concentration shall not exceed the values specified in ANSI/ASME B106.1M and shall have a safety factor of at least two for all continuous cyclic load conditions and shall have a fatigue life as specified in 2.2.5.

2.4.5.1.6 For rotating exciter assemblies that are mated axially to the main shaft with a flanged connection, the connection shall withstand torques greater than those arising from normal operation, including forces experienced during starting and two- and three-phase fault conditions at the machine terminals.

2.4.5.1.7 When vibration and/or axial-position probes are furnished, or when provisions for probes are required as described in 3.8, the rotor shaft sensing areas to be observed by the radial probes shall be concentric with the bearing journals. All sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe-tip diameter plus one half of the total end float on each side of the probe. These areas shall not be metalized, sleeved, or plated. The final surface finish shall be a maximum of 0.8 μm (32 μin.) R_a, preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in API 670 or otherwise treated so that the combined total electrical and mechanical runout does not exceed the following when measured in accordance with 4.3.3.1.

a) For areas to be observed by radial vibration probes, 25 % of the allowed unfiltered peak-to-peak vibration amplitude or 6.4 μm (0.25 mils), whichever is greater.

b) For areas to be observed by axial-position probes, 12.7 μm (0.5 mils).

• **2.4.5.1.8** When specified, shaft forgings shall be ultrasonically inspected in accordance with 4.2.2.3.1.

● **2.4.5.1.9** The shaft extension type shall be as specified on the data sheets. Tapered shaft extension and integral flanges shall conform to the requirements of API 671 or ISO R/775. Cylindrical shaft extensions shall conform to the requirements of AGMA 9002 or ISO R/773, ISO R/774 and ISO R/775. Surface finish of the shaft for a hydraulic mounting or removal design-coupling hub shall be 0.8 μm (32 μin.) Ra or better at the hub mounting area. When tapered shaft extensions are supplied, the fit shall be verified with a ring gage supplied by the purchaser of the coupling. When integral flanges are supplied, the machine purchaser shall provide flange geometry and the drill fixture (or template), if required.

2.4.5.2 Assembly

2.4.5.2.1 On laminated poles, laminated pole shoes, and laminated cylindrical rotors, the laminations shall have no burrs larger than 0.076 mm (0.003 in.). Laminations shall be distributed to minimize uneven buildup and evenly distribute magnetic properties in grain orientation. The method of assembly shall prevent scoring of the shaft surface, assure positive positioning, and minimize bowing (all non-transient torque conditions shall be transmitted via rotor core/shaft interference fit).

2.4.5.2.2 Machines with fabricated-bar amortisseur windings shall be furnished with copper, copper alloy bars and end rings.

2.4.5.2.3 Where retaining rings are used, they shall be without circumferential joints and of a material not susceptible to stress cracking due to exposure to moisture, chlorides or other airborne contaminates.

2.4.5.2.4 To ensure good heat transfer to the rotor core and to limit vibration and fatigue of bars, all bars shall be maintained tightly in their slots. The rotor cage shall be maintained centered (e.g. swedged, center locked or pinned) to prevent axial movement.

2.4.5.2.5 The method by which the bars are attached to the current-carrying end ring shall be selected to minimize localized heating and the nonuniform stresses that result. The bars shall be radially supported as necessary in the current-carrying end ring to prevent the braze or weld from being overstressed and maximize the joint contact area. The metal joining material shall not be subject to attack by hydrogen sulfide (that is, it shall be free from phosphorus). Inert-gas welding, induction brazing, and gas brazing are the acceptable methods. Outward bending of the ends of the rotor bars and articulation of the shorting ring shall be limited by design, material selection, or shrunk-on or fitted non magnetic metallic retaining rings.

2.4.5.2.6 The material and processes used to fabricate copper and copper alloy bars and end rings shall be selected to minimize hydrogen embrittlement.

● **2.4.5.2.7** Rotors shall be designed to withstand overspeeds without permanent mechanical deformation (see 2.1.5). Overspeed requirements more stringent than those of NEMA MG 1 or IEC 60034-1 will be specified by the purchaser.

2.4.5.2.8 The end ring and bars shall be replaceable without damage to air passages or laminations.

2.4.5.2.9 Rotors with removable solid pole heads shall have easily removable field coils. The bolts that retain the laminated or solid pole heads shall be secured by a method that allows easy removal of the bolts and is approved by the purchaser.

2.4.5.2.10 Fans may be integrally cast with the end rings or separately mounted. Separable fans shall be permanently indexed angularly and axially and mounted by one of the following methods:

a) split hub on shaft;

b) bolted or welded to the rotor retaining ring or to the field winding support;

c) shrink fit or directly bolted on shaft or hub; or

d) spider or endplate mounted.

Slip-fitted fans secured to the shaft by means of set screws only are not acceptable. Removal and reassembly of the fans on the rotor shall not change the rotor balance enough to exceed the allowable residual unbalance limits.

2.4.5.2.11 Fans shall be capable of being balanced in accordance with 2.4.6.3. Welding is not an acceptable means of balancing a fan.

2.4.5.2.12 For machines having fans with tip speeds in excess of 75 m/s (15,000 ft/min), the design of the stressed parts of fans shall include proper evaluation of stress concentration factors (SCF) for the geometry. The design of stressed rotating parts shall include fillets that will limit the SCF. Areas of concern include the fan, blade-to-disk intersections, keyways, and shaft section changes. All accessible areas of welds on fans shall be subjected to magnetic particle or liquid penetrant inspection.

2.4.5.2.13 If field-winding braces are installed in interpolar spaces of salient-pole machines, to avoid excessive hot spots, they shall be located so that the fan can draw adequate cooling air through the interpolar spaces.

2.4.5.2.14 Field poles for machines with a rotor spider design shall be mounted and secured in a manner to prevent undue stresses on mounting bolts which can result in premature failure. Bolt hole diameters in the spider and bolt clearances shall be sized to ensure that the bolts remain properly centered under all conditions of installation and operation.

2.4.6 Dynamics

2.4.6.1 Resonances

♦ **2.4.6.1.1** Lateral natural frequencies which can lead to resonance amplification of vibration amplitudes shall be removed from the operating speed frequency and other significant exciting frequencies (see 1.5.5) by at least 15 %. Machines intended for continuous operation on ASDs shall meet this requirement over the specified speed range. If it is not possible to avoid lateral natural frequencies by at least 15 % in an ASD application, a well damped resonance (see 4.3.5.3 c and Annex H) may be permitted with purchaser approval.

● **2.4.6.1.2** If the machine is to be supported in the field by a structure other than a massive foundation, the purchaser will specify this on the data sheets, and the vendor shall supply the following data, as a minimum, to the purchaser so that a system dynamic analysis can be made and an adequate foundation designed:

a) a detailed shaft section model with masses, mass elastic data including mass and rotational inertia (WK^2), shaft section lengths, and inner and outer diameters;

b) for the minimum and maximum design bearing clearances and maximum oil operating temperature, an eight-coefficient bearing model with damping and spring constants;

c) horizontal and vertical bearing-housing and frame stiffness;

d) foundation dynamic stiffness requirements.

NOTE 1 The rigidity of a foundation is a relative quantity. It must be compared with the rigidity of the machine bearing system. The ratio of bearing-housing vibration to foundation vibration is a characteristic quantity for the evaluation of foundation flexibility influences. One indication that a foundation is massive is if the vibration amplitudes of the foundation (in any direction) near the machine feet or base frame are less than 30 % of the amplitudes that could be measured at the adjacent bearing housing in any direction.

NOTE 2 A massive foundation is recommended. See 2.4.2.1 for information on the foundation natural frequencies.

2.4.6.1.3 Resonances of structural support systems that are within the vendor's scope of supply shall not occur within the specified operating speed range or the specified separation margins.

2.4.6.2 Dynamic Analysis

• **2.4.6.2.1** When specified, the vendor shall provide a lateral critical speed analysis of the machine to assure acceptable amplitudes of vibration at any speed from zero to trip. The vendor shall identify the foundation data required from the purchaser to perform this analysis. When the vendor provides a machine modal analysis model that is utilized in the system/train analysis, the accuracy of that model shall be confirmed during final test. If the first critical speed identified by the vendor model differs from the test results by more than ± 5 %, then the vendor model shall be updated as necessary. (This only applies if the first critical speed is identified by test to be below the specified maximum overspeed.)

2.4.6.2.2 The damped unbalanced response analysis shall include but shall not be limited to the following considerations.

a) Foundation stiffness and damping.

b) Support (bearing-housing/support and bearing tilting pad, pivot or shell) stiffness, mass, and damping characteristics, including effects of rotational speed variation. The vendor shall state the support system values used and the basis for these values (for example, tests of identical rotor support systems, or assumed values).

c) Bearing lubricant-film stiffness and damping characteristics including changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances, and maximum to minimum clearances.

d) Starting conditions, operating speed ranges (including agreed-upon test conditions if different from those specified), trip speed, and coast-down conditions. The analysis of the starting and coastdown conditions shall allow for any resonance to fully evolve. If the acceleration and deceleration of the shaft string is taken into consideration to limit the evolution of any resonance, this shall be clearly stated and presented in addition to the above results.

e) Rotor masses, including the stiffness, and damping effects (for example, accumulated fit tolerances).

f) Mass moment of the coupling half.

g) Asymmetrical loading (e.g. eccentric clearances).

h) For machines equipped with antifriction 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.

i) The location and orientation of the radial vibration probes which shall be the same in the analysis as in the machine.

j) Unbalanced electromagnetic pull (UMP).

2.4.6.2.3 In the case of a non-massive foundation, dynamic foundation stiffness shall be mutually agreed by the vendor of the electrical machine and the vendor who has responsibility of the train. In this case, an adequate model of the machine shall be given to the vendor who has the responsibility for the train.

2.4.6.2.4 Separate damped unbalanced response analysis shall be conducted for each critical speed within the speed range of zero to the next mode occurring above the maximum operating speed. Unbalance shall analytically be placed at the locations that have been determined by the undamped analysis to affect the particular mode most adversely. For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads and shall be applied at the location of maximum displacement. For conical (asymmetric) modes, an unbalance shall be added at the location of maximum displacement nearest to each journal bearing. These unbalances shall be 180° out of phase and of magnitude based on the static load on the adjacent bearing Figure 1 shows the typical mode shapes and indicates the location and definition of U for each of the shapes. The magnitude of the unbalances shall be 4 times the value of U as calculated by Equations (2) and (3).

In SI units

$$U = 6350\ W/N \tag{2}$$

In Customary units

$$U = 4\ W/N \tag{3}$$

where

- U is the input unbalance for the rotor dynamic response analysis in g-mm (ounce-in.);
- N is the operating speed nearest to the critical speed of concern, in revolutions per minute; and
- W is the journal static load in kg (lb), or for bending modes where the maximum deflection occurs at the shaft ends, the overhung mass (that is the mass of the rotor outboard of the bearing) in kg (lb). See Figure 1.

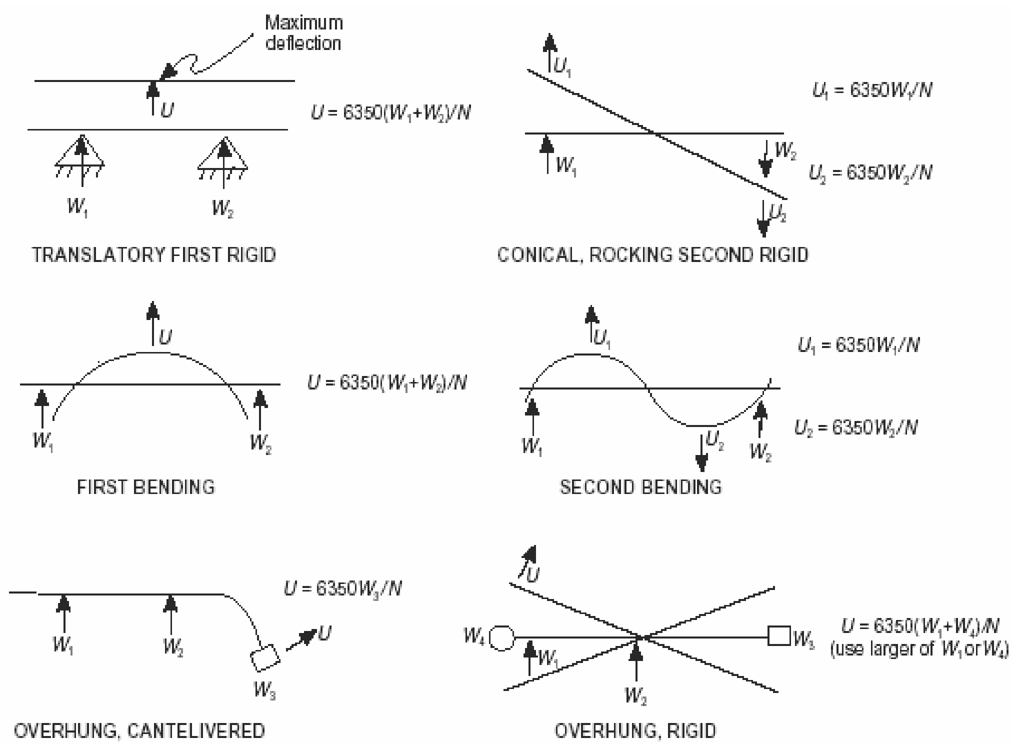


Figure 1—Typical Rotor Mode Shapes

NOTE For machines rated at less than or equal to 1800 rpm it may be necessary to increase the weight of the added unbalance weights to get a sufficient unbalance response.

2.4.6.2.5 If an unbalance response analysis has been performed and the foundation data used in the unbalanced response analysis are significantly different from the test room conditions, additional analyses shall be made for use with the verification test specified in 4.3.5.3. The location of the unbalance shall be determined by the vendor. Any test stand parameters which influence the results of the analysis shall be included.

2.4.6.2.6 As a minimum, the unbalanced response analysis shall produce the following.

a) Identification of the frequency of each critical speed in the range from zero to the next mode occurring above the maximum operating speed.

b) Frequency, phase and response amplitude data (Bode plots) at the vibration probe locations through the range of each critical speed resulting from the unbalance specified in 2.4.6.2.4.

c) The plot of the deflected rotor shape for each critical speed resulting from the unbalances specified in 2.4.6.2.4, showing the major-axis amplitude at each coupling, the centerlines of each bearing, the locations of each radial probe, and at each seal throughout the machine as appropriate. The minimum design diametral running clearance of the seals shall also be indicated.

d) Additional Bode plots that compare absolute shaft motion with shaft motion relative to the bearing housing for machines where the support stiffness is less than 3.5 times the oil-film stiffness.

• **2.4.6.2.7** When specified, the assigned vendor shall perform a steady-state and transient torsional and stress analysis of the complete mechanical train, including gears, pumps, compressors, fans, shaft driven auxiliaries, and the effects of the electrical system including ASDs, if applicable, etc. The equipment vendors shall be responsible for providing the data required for the torsional analysis to the purchaser or the party responsible for the analysis, as specified, to allow for any system modification that might be necessary to meet the requirements of 2.4.6.2.7.3 through 2.4.6.2.7.6. Full details, including schedule requirements, shall be agreed at the time of order placement and again at the design review meeting (see 6.5).The torsional analysis shall include but shall not be limited to the following:

2.4.6.2.7.1 Excitation of torsional natural frequencies may come from many sources which 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 startup of synchronous electric motors and phase-to-phase, three phase, and if applicable, phase-to-ground faults;

d) torsional excitation resulting from electric motors, reciprocating engines, and rotary type positive displacement machines;

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

f) one and two times line frequency;

g) running speed or speeds; and

h) harmonic frequencies from an ASD.

2.4.6.2.7.2 The torsional analysis shall include but not limited to the following:

a) a complete description of the method used to complete the analysis;

b) a graphic display of the mass-elastic system;

c) a tabulation identifying the polar mass moment of inertia and torsional stiffness for each component identified in the mass-elastic system;

d) a graphic display or expression of any torsional excitation versus speed or time;

e) for the starting torsional study, the motor speed torque curve and the twice slip frequency pulsating torque curve shall be furnished for both rated voltage at an infinite bus and the minimum starting conditions; and

f) a graphic display of torsional critical speeds and deflections (a mode shape diagram).

2.4.6.2.7.3 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).

2.4.6.2.7.4 Torsional natural frequencies at two or more times only running speed shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall be shown to have no adverse effect.

♦ **2.4.6.2.7.5** For ASDs, the torsional analysis shall also verify that the calculated shaft torque, at any resonance points up to the maximum operating speed does not result in shaft torsional stresses that exceed the allowed maximum for the shaft design. Any design changes required to achieve this shall be agreed by the assigned vendor, purchaser, ASD supplier and motor manufacturer.

2.4.6.2.7.6 When torsional resonances are calculated to fall within the margin specified in 2.4.6.2.7.3 (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.

2.4.6.3 Balancing

2.4.6.3.1 All rotors 600 rpm and above shall be dynamically balanced in two or more planes as complete assemblies. Rotors operating at speeds in excess of the first lateral critical bending mode shall be balanced in at least three planes, including a center plane at or near the axial geometric center of the rotor assembly. If a center balance plane is not practical, the manufacturer shall propose an alternate balancing arrangement that will satisfy the requirements of paragraph 4.3.5.4, for purchaser approval. When a keyway is provided for a coupling hub, the rotor shall be balanced with the keyway fitted with a crowned half-key, or its dynamic equivalent. Where rotor mounted fan(s) are utilized on two, four and six pole machines, the complete rotor assembly shall also be balanced prior to mounting the fan(s) except where the fan contains a main rotor balance plane. Individual fans which do not contain a main rotor balance plane shall be dynamically balanced independently. If the exciter is not component balanced, means shall be taken to allow for reassembly in the original position.

2.4.6.3.2 Balance weights and fasteners added to the final assembly shall be readily removable and replaceable and made of AISI 300 series (or ISO 3506) stainless steel or a purchaser-approved corrosion-resistant material. If parent metal is to be removed to achieve balance, it shall be removed only from an area designed for that purpose. The material shall be removed by drilling in a manner that maintains the structural integrity of that component and does not cause harmful or distortive hot spots during operation. Chiseling, grinding, sawing, or torch burning is not permitted. The use of solder or similar deposits for balancing purposes is not acceptable. Balance corrections shall not be made to the fan blades.

• **2.4.6.3.3** When specified, a balanced half-coupling shall be mounted on the rotor, and the rotor balance shall be rechecked in accordance with 4.3.1.6.2. Any increase in unbalance shall be reported to the purchaser. Any corrections to the rotor balance shall be mutually agreed upon by the purchaser and the machine vendor. Corrections to the coupling balance shall be mutually agreed upon by the purchaser, coupling vendor (if applicable) and machine vendor.

NOTE Excessive radial shaft runout can cause high vibration after a balanced coupling has been mounted on the rotor. Shaft-extension radial runout should be checked against the vendor's drawings prior to making any corrections.

2.4.6.3.4 For the final balancing of the rotor in the balancing device, the maximum allowable residual unbalance in the correction plane (journal) shall be calculated from the following equations:

In SI units,

$$UB = 6350W_r/N_{mc} \qquad (2)$$

In US Customary units

$$UB = 4W_r/N_{mc} \qquad (3)$$

where

UB is the residual unbalance, in gram-mm (ounce-in.)

W_r is the journal static loading, determined from the mass distribution in the rotor, in kg (lb) (Typically one-half rotor weight)

N_{mc} is the maximum continuous speed, in revolutions per minute.

2.4.6.3.5 Where a rotor is unsymmetrical, or the correction planes are unsymmetrically located, the allocation of residual unbalance between the correction planes by reference to journal static loading may not be appropriate. In this case the proportionate allocation of residual unbalance to the correction planes should be determined by reference to ISO 1940/1. However, the total residual unbalance shall be less than 6350 W/N_{mc} ($4W/N_{mc}$), where W is the rotor mass, not the ISO 1940/1 balance grade.

• **2.4.6.3.6** When specified, the residual unbalance of the rotor shall be determined in accordance with 2.4.6.3.4 and Annex F.

NOTE Annex F provides a method of determining the residual unbalance remaining in the completely assembled rotor and balancing machine sensitivity check.

2.4.6.3.7 A balancing device is either a conventional balancing machine or the actual machine frame assembly with the rotor installed. When the machine frame is used as a balance device, the residual unbalance of the rotor shall be determined in accordance with 2.4.6.3.6 and Annex F.

2.4.6.4 Vibration

Machines shall be designed so that they meet the acceptance criteria stated in 4.3.3.

2.4.7 Bearings, Bearing Housings and Seals

2.4.7.1 Bearings

2.4.7.1.1 Unless otherwise specified, spherically seated hydrodynamic radial bearings (sleeve or tilting pad, for example) shall be provided on all horizontal machines.

NOTE To limit bearing babbitt wear, bearings and lubrication should be evaluated to determine if hydraulic jacking means should be applied in machines which require multiple starts per day.

2.4.7.1.2 Hydrodynamic radial bearings shall be split for ease of assembly, precision bored, and of the sleeve or pad type with steelbacked or bronze-backed, babbitted replaceable liners, pads, or shells. These bearings shall be equipped with anti-rotation pins and shall be positively secured in the axial direction. The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping to limit rotor vibration to the maximum specified amplitudes while the machine is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency if that frequency is a normal operating speed. The bearings on each end of horizontal machines shall be identical. Under certain circumstances it may be impractical to supply identical bearings, e.g., lateral critical speed or torsional resonance considerations, or three bearing machines. For those cases, the vendor shall propose alternative solutions for approval by the purchaser.

The design of the bearing housing shall not require removal of the lower half of end bells or plates, ductwork, or the coupling hub to permit replacement of the bearing liners, pads, or shells.

● **2.4.7.1.3** When specified, antifriction bearings shall be used for horizontal machines provided that the following conditions are met:

a) The dN factor is less than 300,000. [The dN factor is the product of bearing size (bore) in mm and the rated speed in revolutions per minute].

b) Antifriction bearings meet an ABMA L_{10} rating life of either 100,000 hours with continuous operation at rated conditions or 50,000 hours at maximum axial and radial loads and rated speed. (The L_{10} rating life is the number of hours at rated bearing load and speed that 90 % of a group of identical bearings will complete before the first evidence of failure. See ABMA Standard 9 or ABMA Standard 11, as applicable, or ISO 281 or ISO 76.

2.4.7.1.4 Antifriction guide bearings may be used for vertical machines provided the conditions of 2.4.7.1.3, items a and b are satisfied.

2.4.7.1.5 Antifriction thrust bearings may be used for vertical machines provided that the following conditions are met.

a) Thrust bearings for vertical motors shall be on top.

b) Multiple bearings to accommodate thrust in the same direction shall not be permitted.

c) The thrust bearings for vertical machines shall be rated for ABMA L_{10} life of at least 5000 hours with continuous operation at 200 % of the maximum up and down thrust which may be developed during starting, stopping or while operating at any capacity on the rated performance curve. Vendor shall notify the purchaser if testing is affected by the presence of bearing springs or the re-orientation of mounting position during testing.

NOTE 1 Spherical roller bearings often have springs designed to compress with the down thrust and if the thrust is less than design, the rotor rides higher than normal and there will be increased vibration during no load testing.

NOTE 2 To avoid condensation, the minimum inlet water temperature to water cooled bearing housings should preferably be above the ambient air temperature.

2.4.7.1.6 Antifriction bearings shall be retained on the shaft and fitted into housings in accordance with the requirements of ABMA Standard 7 or ISO 286-1 or 286-2; however, the device used to lock ball thrust bearings to the shaft shall be restricted by a nut with a tongue-type lockwasher, for example, Series W per ABMA Standard 8.2.

2.4.7.1.7 Except for the angular-contact bearings and lower guide bearings in vertical machines, antifriction bearings shall have an internal clearance fit equivalent to ABMA Symbol 3, as defined in ABMA Standard 20 or ISO 15, 492, or 5753. Single- or double-row bearings shall be of the deep-groove (Conrad) type. Filling-slot (maximum-load) antifriction bearings shall not be used. Bearings shall be commercially available from more than one bearing manufacturer.

2.4.7.1.8 Bearings shall be electrically insulated. A shorting device shall be provided in the bearing housing on the drive end. For double-end drivers, the coupling on one end also shall be electrically insulated and the bearing housing shorting device provided on the opposite end.

♦ • **2.4.7.1.9** For ASD applications where it is determined that the bearing currents may be non characteristic, or where the rotor may become electrically charged, special measures may be required, and shall be proposed by the vendor. These measures may involve special isolation procedures, shaft grounding brushes or winding connection design modifications. If grounding brushes are used, they shall be redundant and replaceable without shutting down the machine. When specified, there shall be a monitoring system installed to annunciate the need for brush replacement.

2.4.7.1.10 Hydrodynamic thrust bearings for vertical machines shall be of the babbitted multiple-segment type. Tilting-pad bearings shall incorporate a self-leveling feature which assures that each segment carries an equal share of the thrust load. With minor variation in pad thickness, each pad shall be designed and manufactured with dimensional precision (thickness variation) that will allow interchange of individual pads. The thrust collar shall be replaceable. Fretting and axial movement shall be prevented. The thrust faces of the collar shall have a surface finish of not more than 0.4 μm (16 μin.) R_a and the total indicated axial runout of either thrust face shall not exceed 12 micrometers (500 μin.). Split thrust collars are not acceptable.

2.4.7.1.11 Hydrodynamic thrust bearings for vertical machines shall be selected such that under any operating condition the load does not exceed 50 % of the bearing manufacturer's ultimate load rating. The ultimate load rating is the load that will produce the minimum acceptable oilfilm thickness without inducing failure during continuous service or the load that will not exceed the creep initiation or yield strength of the babbitt at the location of maximum temperature on the pad, whichever load is less. In sizing creep initiation thrust bearings, consideration shall be given to the following for each specific application:

a) the thrust loads from the driven equipment under all operating conditions;

b) the shaft speed;

c) the temperature of the bearing babbitt;

d) the deflection of the bearing pad;

e) the minimum oil film thickness;

f) the feed rate, viscosity, and supply temperature of the oil;

g) the design configuration of the bearing;

h) the babbitt alloy; and

i) the turbulence of the oil film.

The sizing of hydrodynamic thrust bearings shall be reviewed and approved by the purchaser.

2.4.7.1.12 If a non-axially locating gear- or spline-type coupling (non-limited end-float type, where sliding may take place at the tooth mesh) must be considered, the transmitted external axial force shall be calculated from Equations (4) and (5).

In SI units,

$$F = 19095\mu\frac{P_r}{N_r d} \tag{4}$$

In US Customary Units

$$F = 126000\mu\frac{P_r}{N_r d} \tag{5}$$

where

F is the external force, in kilo-Newtons (lb);

P_r is the rated power, in kilowatts (horsepower);

N_R is the rated speed, in revolutions per min;

d is the gear tooth pitch circle diameter (CD) in mm (in.) (use d = 2 times the shaft diameter if coupling details are unknown);

μ is the coefficient of friction at the gear teeth (use = 0.25 unless a definite value is available).

2.4.7.1.13 Thrust loads for diaphragm-like and disk-type couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

2.4.7.1.14 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 40 °C (104 °F).

a) For pressurized systems that provide a bearing inlet oil temperature of 50 °C (122 °F) or below, the oil passing through the bearing during shop testing and in operation shall not exceed a temperature rise of 20 °C (36 °F) and the maximum bearing metal temperature shall not exceed 93 °C (200 °F).

b) For ring-oiled or splash systems, oil sump temperature shall not exceed 80 °C (176 °F) on test and in operation. Bearing metal temperature on test and in operation shall not exceed 93 °C (200 °F).

NOTE 1 Machines equipped with ring-oiled or splash lubrication systems may not reach temperature stabilization during performance tests of short duration. If the purchaser desires temperature stabilization testing, this requirement should be stated in the inquiry and addressed by the vendor in the proposal.

NOTE 2 To avoid condensation, the minimum inlet water temperature to water cooled bearings should preferably be above the ambient air temperature.

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

• **2.4.7.1.15** When specified, a bearing-oil temperature sensor shall be provided on the bearing housing of non-pressure-fed bearings or in the drain lines of pressure fed bearings. The sensor shall be removable without loss of oil.

2.4.7.1.16 At ambient temperature, the fit between the outside of the bearing shell and the bearing housing shall be zero clearance to an interference fit.

2.4.7.2 Bearing Housings

2.4.7.2.1 Bearing housings for pressure-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 and to allow a sufficient oil level for operation.

• **2.4.7.2.2** On horizontal machines, bearing housings for self oil-lubricated bearings shall have oil reservoirs of sufficient depth to serve as settling chambers. The housings shall be provided with tapped and plugged fill and drain openings at least DN 15 ($^1/_2$ in. NPS)

A permanent indication of the proper 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. If the oil-level indicator breaks, the resulting drop in oil level shall not result in loss of bearing lubrication, that is, reduction of the oil level below the level required for oil-ring operation.

When specified, the housings shall be equipped with constant-level oilers at least 0.25 L (8 oz) in size, with a positive level positioned (not a set screw), clear glass containers, protective wire cages, and supplemental support in addition to the piping.

2.4.7.2.3 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.

2.4.7.2.4 Bearing housings shall be positively located by cylindrical precision dowels or rabbetted fits. Bearing housings and support structures shall be designed so that, upon assembly, none of the air-gap measurements taken in at least three positions (spaced 90 degrees apart) at each end of the stator deviates from the limits given below for the stator gap, as defined by the following equation:

$$D = [(H - L)/A]100 \tag{6}$$

where

D is the percentage deviation;

H is the highest of the readings at one end of the stator;

L is the lowest of the readings at the same end of the stator; and

A is the average of the readings at the same end of the stator.

The air gap between the exterior of the rotor and the interior of the stator must be measured at both ends of the stator. Measurements should be taken at the same positions on both ends. The percentage deviation (D) shall not exceed 10 %. This data shall be recorded and made part of the final report. To allow for accurate measurement, stator and rotor surfaces at the measuring positions shall be free from resin buildup.

2.4.7.2.5 Bearing housings shall be machined for mounting vibration detectors as described in 3.8.1.

• 2.4.7.3 Shaft Seals

Shaft seals shall conform to the following.

a) Enclosure or housing shaft seals shall be made from nonsparking materials and centerable about the shaft. Where aluminum is used, it shall have a copper content of less than 0.2 %. Split type seals shall be provided to allow replacement without shaft or coupling removal. Where end-shield-supported bearings are used, the inner seal shall be maintained at atmospheric pressure. Pressure balancing from the cooling fan shall be by use of copper or steel tubing, unless other materials are approved by the purchaser. Seals shall be designed to minimize the entry of fumes, dirt, and other foreign material into the stator enclosure. When specified, seals shall be constructed so that a purge gas can be introduced. If possible, self-aligning seals shall be used.

b) When specified, the shaft seals shall be fabricated from electrically non-conducting materials.

c) Bearing housings for horizontal machines shall be equipped with split labyrinth-type end seals and deflectors where the shaft passes through the enclosure. Lip-type seals shall not be used. The sealing system shall meet the requirements of IP 55. If replaceable shaft seals are used to achieve this degree of protection, they shall be the non-contact or non-contacting while rotating type with a minimum expected seal life of 5 years under usual service conditions. No oil shall leak past the seals during both stationary and operating conditions, while circulating lube oil.

2.4.7.4 Oil Mist Provisions

• **2.4.7.4.1** The requirements of 2.4.7.4.2 through 2.4.7.4.6 apply when oil mist lubrication is specified.

2.4.7.4.2 An oil mist inlet connection, $^{1}/_{4}$ NPT, shall be provided in the top half of the bearing housing. The pure- or purge-oil mist fitting connections shall be located so that oil mist will flow through rolling element bearings. On pure-mist systems, there shall be no internal passages to short-circuit oil mist from inlet to vent.

2.4.7.4.3 A $^{1}/_{4}$ NPT vent connection shall be provided on the housing or end cover for each of the spaces between the rolling element bearings and the housing shaft closures. Alternatively, where oil mist connections are between each housing shaft closure and the bearings, one vent central to the housing shall be supplied. Housings with only sleeve-type bearings shall have the vent located near the end of the housing.

2.4.7.4.4 Shielded or sealed bearings shall not be used.

2.4.7.4.5 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 mist lubrication is specified, these items shall be provided and the oiler shall be piped so that the oiler is maintained at the internal pressure of the bearing housing.

NOTE At process operating temperatures above 300 °C (570 °F), bearing housings with pure-oil mist lubrication may require special features to reduce heating of the bearing races by heat transfer through the shaft. Typical features are:

a) heat sink type flingers;

b) stainless steel shafts having low thermal conductivity;

c) thermal barriers;

d) fan cooling;

e) purge oil mist lubrication (in place of pure oil mist) with oil (sump) cooling.

2.4.7.4.6 The oil mist supply and drain fittings will be provided by the purchaser.

2.4.8 Lubrication

2.4.8.1 Unless otherwise specified, hydrodynamic bearings shall use hydrocarbon oil and shall be arranged for ring-type lubrication in accordance with the bearing manufacturer's recommendations. Oil rings shall have a minimum submergence of 6 mm ($^{1}/_{4}$ in.) above the lower edge of the bore of the oil ring. If oil rings are not practical, as with tilting pad bearings, the vendor shall advise and obtain approval from the purchaser. Where the shaft circumferential speed exceeds the limits for the use of oil rings, a pressurized (forced) oil system shall be used.

The vendor shall notify the purchaser when oil rings are not provided with the bearings so that adequate provision can be made for lubrication during loss-of-oil pressure emergency coast-down situations.

2.4.8.2 Oil slingers shall have mounting hubs to maintain concentricity and shall be positively secured to the shaft.

• **2.4.8.3** When specified, 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. The thermostatic enclosure shall be compatible with the area classification requirements.

• **2.4.8.4** Where a pressurized or circulating lubrication system is required by a gear, the mechanical equipment, or both, the electrical equipment bearing oil may be supplied from that system, when specified. The purchaser will specify the supplier of the complete lubrication system.

• **2.4.8.5** Where oil is supplied from a common system to two or more machines (such as a compressor, a gear, and a motor), the oil's characteristics will be specified on the data sheets by the purchaser on the basis of mutual agreement with all vendors supplying equipment served by the common oil system.

NOTE 1 The usual lubricant employed in a common oil system is a hydrocarbon oil that corresponds to ISO Grade 32, as specified in ISO 3448.

NOTE 2 If flammable or combustible materials are handled in some part of the equipment train, means should be taken to assure that these materials can not enter the electrical machine through a common lube oil system. In some cases, this may require a separate lube oil system for the electrical machine.

• **2.4.8.6** When specified, pressurized oil systems shall conform to the requirements of API 614 or ISO 10438-1.

2.4.8.7 When supplied with the machine, oil piping (inlet and drains), orifices and throttle valves shall be AISI 300 series stainless steel.

2.4.8.8 The user will specify on the data sheet the type of oil used for the application.

NOTE The use of synthetic lubricants for machine bearings may require a special design. When the use of synthetic lubricants is specified, it is important that the user inform the vendor of the specific type and brand used.

2.4.9 End Play and Couplings

2.4.9.1 Horizontal hydrodynamic radial bearing machines shall have a total end play of at least 12 mm (0.5 in.). The design of the machine shall ensure that the magnetic center shall be within 20 % of the total end float from the center of the end float limit indicators [e.g. 2.4 mm (0.1 in.) for a 12 mm (0.5 in.) total end float]. Running at this position provides sufficient clearances between the rotor journal shoulders and the bearing and seal faces under all operating conditions when a limited end float coupling is used (2.4.9.2).

2.4.9.2 Flexible couplings used with horizontal hydrodynamic radial bearing machines shall be of the limited-end-float-type. The total end float shall be limited to 4.8 mm ($^3/_{16}$ in.).

2.4.9.3 When horizontal hydrodynamic bearings are provided, the machine shall have a permanent indicator to show the actual limits of end float and magnetic center. The indicator shall be durable and shall be adjacent to the drive end shaft shoulder.

• **2.4.9.4** When specified, the electrical machine vendor shall install the half coupling.

2.4.10 Materials

2.4.10.1 General

2.4.10.1.1 All components used for the purchaser interface shall be in accordance with applicable local standards (e.g. ANSI standard threads in the United States).

• **2.4.10.1.2** The purchaser will specify any corrosive agents present in the environment, including constituents that may cause stress corrosion cracking.

2.4.10.1.3 Where mating parts such as studs and nuts of 300 series stainless steel or materials having similar galling tendencies are used, they shall be lubricated with a suitable antiseizure compound.

2.4.10.1.4 Unless specifically approved by the purchaser, no component shall be repaired by plating, plasma spray, metal spray, impregnation or similar methods.

2.4.10.2 Castings

2.4.10.2.1 The vendor shall specify the material grade of castings on the data sheets.

2.4.10.2.2 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting or chemical methods. Any other cleaning method requires approval by the purchaser. Mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

2.4.10.2.3 Ferrous castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 2.4.10.2.3.1 and 2.4.10.2.3.2.

2.4.10.2.3.1 Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure based on the requirements of Section IX of the ASME Code, (ISO 9013).

2.4.10.2.3.2 Cast gray iron or nodular iron may be repaired by plugging within the limits specified in ASTM A278, ASTM A395, or ASTM A536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All necessary repairs not covered by ASTM specifications shall be subject to the purchaser's approval.

2.4.10.2.4 Fully enclosed cored voids, including voids closed by plugging, are prohibited.

2.4.10.3 Welding

2.4.10.3.1 Structural welding, including weld repairs, shall be performed by operators and procedures qualified in accordance with AWS D1.1 and ISO Catalog 25.160.10 through 25.160.50. Other welding codes may be used if specifically approved by the purchaser.

2.4.10.3.2 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 applicable qualified procedures.

2.4.10.3.3 All butt welds shall be continuous full-penetration welds.

2.4.10.3.4 Intermittent welds, stitch welds, and tack welds are not permitted on any structural part of the machine,. If specifically approved by the purchaser, intermittent welds may be used where significant problem-free operating experience exists and well-established design procedures are available.

2.4.10.3.5 Welding of or to shafts is not acceptable for balancing purposes, on finished shafts, or on two-pole machines. Any shafts or spiders subjected to welding shall be post-weld stress relieved prior to finish machining.

• **2.4.10.4 Low Temperature Service**

To avoid brittle failures, materials and construction for low temperature service shall be suitable for the minimum design metal temperature in accordance with the codes and other requirements specified. The purchaser and the vendor shall agree on any special precautions necessary with regard to conditions that may occur during operation, maintenance, transportation, erection, commissioning and testing.

NOTE Good design practice should be followed in the selection of fabrication methods, welding procedures, and materials for vendor furnished steel pressure retaining parts that may be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for many materials in internationally recognized standards such as the ANSI/ASME Code and ANSI standards are based on minimum tensile properties. Some standards do not differentiate between rimmed, semi killed, fully killed hot-rolled, and normalized material, nor do they take into account whether materials were produced under fine- or coarse-grain practices. The vendor should exercise caution in the selection of materials intended for services below –30 °C (–20 °F)

2.4.10.5 Protective Grills or Metal Screens

Protective grills or metal screens shall be fabricated from not less than 1.25 mm (0.05 in.) AISI 300 series stainless steel with a maximum mesh of 6.0 mm ($^1/_4$ in.). On enclosures equipped with filters, the screens downstream of the filters may have a maximum mesh of 12.7 mm ($^1/_2$ in.).

2.4.10.6 Fans

2.4.10.6.1 Fan systems, blades, and housings shall be designed to prevent sparking as a result of mechanical contact or static discharge. They shall be constructed to minimize failure from corrosion or fatigue. When specified, the vendor shall demonstrate to the purchaser's satisfaction that the nonsparking qualities and durability required are provided by the fan system.

NOTE Materials that are typically used are: aluminum (with a copper content of less than 0.2 %), bronze, reinforced thermosetting conductive plastic (to bleed off static charges) or epoxy coated steel fans.

2.4.10.6.2 Shaft mounted cooling fans, and any other similar shaft mounted components, shall be designed and constructed so that they will not resonate at any frequency within the defined operating speed range.

• **2.4.10.6.3** *Auxiliary motor driven fans*. When specified on the data sheets cooling shall be provided by motor driven auxiliary fans. Fans may be directly mounted on the motor enclosure or in the case of TEPV motors on the external ducting. In all cases the fan motor assembly shall be designed for easy access and replacement. Fan assemblies shall meet the requirements of 2.4.10.6.1.

Motors shall be in accordance with IEEE 841.

2.4.10.7 Stator Lamination Core Plate

Stator lamination core plate shall be of at least C-5 quality in accordance with ASTM A345, or IEC 60404-1-1. C3 quality plate shall not be used dispersed or as a coating over C5 quality plate. The stator core shall be capable of withstanding winding burnout for rewind at a temperature of 400 °C (750 °F) without damage or loosening.

2.4.10.8 Heat Exchangers

Heat exchangers shall conform to the following.

- • a) Air-to-air exchanger tubes used in the tube-type machines shall be made of copper, copper-based alloy, aluminum, aluminum alloy containing no more than 0.2 % copper, or AISI 300 series stainless steel.

- • b) Water-to-air heat exchanger tubes shall be not less than 15 mm (0.625 in.) outside diameter and 1.25 mm (18 BWG) wall thickness made of 90-10 Cu-Ni material. Purchaser has the responsibility to provide the cooling water chemistry to be checked for material compatibility.

c) On double tube water-to-air coolers, the water side tubes shall conform to 2.4.10.8 b). The air side outer tube material shall be copper or copper based alloy and have a minimum wall thickness of 0.7 mm (0.028 in.).

2.4.11 Nameplates and Rotation Arrows

2.4.11.1 All nameplates and rotation arrows shall be of AISI 300 series stainless steel, securely fastened by pins of similar material, and attached at readily visible locations. All information (including title fields) shall be permanently inscribed, embossed or engraved. Nameplates shall be provided on the machine and on or adjacent to each auxiliary device or junction box.

2.4.11.2 As a minimum, the data listed below shall be clearly stamped on the machine's nameplate(s):

a) vendor's name;

b) serial number;

c) horsepower, kVA or kW;

d) voltages;

e) phase;

f) rated power factor;

g) frequency, in Hz;

h) for antifriction bearings, the manufacturer and model number;

i) for bearings with an external oil supply, the oil flow rate, in L (gal) per minute and the oil pressure required, in kPa (lb per in.^{2}) gauge;

j) full-load current (amps);

k) locked-rotor amperes (amps);

l) full-load speed, in revolutions per min;

m) rated main field current;

n) rated main field voltage;

o) rated exciter current;

p) rated exciter voltage;

q) time rating;

r) temperature rise, in degrees Celsius; the maximum ambient or cooling-air temperature for which the machine was designed; and the insulation system's designation;

s) service factor;

t) starting limitations;

u) location of the magnetic center, per 2.4.9.3, in mm (in.) (from the drive-end bearing housing on a horizontal machine with a sleeve bearing);

v) for machines installed in Class I or Class II, Division 2 or Zone 2 locations, labeling or marking requirements as required in NFPA 70 or IEC 60079-10;

NOTE The "T Code" designations of the two systems are not identical.

w) enclosure type;

x) total machine weight and rotor weight;

y) year of manufacture (e.g. 2006);

z) location of manufacture;

♦ aa) the frequency range for ASD driven units;

♦ ab) type of torque/speed characteristic for which the motor is designed e.g. VT (variable torque) or CT (constant torque) down to a specified speed;

♦ ac) type of inverter for which the motor is intended to be used.

2.4.11.3 Separate connection diagrams or data nameplates shall be located near the appropriate connection box for the following:

a) machines with more than three power leads;

b) space heaters (operating voltage and wattage, and maximum surface temperature or NFPA 70 "T Code" for Class I or II Division 2 or Zone 2 locations);

c) temperature detectors (resistance, in ohms, or junction type);

d) vibration and position detectors (manufacturer and model number);

e) connections for proper rotation (including bidirectional);

f) current transformer secondary leads (when provided) including polarity marks;

g) orifice size;

♦ h) connection diagram for tachometer.

2.4.11.4 When specified, the purchaser's identification information shall be stamped on a separate nameplate.

•

2.5 Excitation System

2.5.1 General Requirements

2.5.1.1 All components of the excitation system shall comply with the requirements of 2.1.1.

2.5.1.2 Over-excitation protection shall be included in the excitation system.

• **2.5.1.3** When specified for motors, the system shall be capable of automatically controlling either power factor or VAR export of the motor and allow for "bumpless" transfer from one mode to another.

2.5.1.4 For generators, the system shall be capable of automatically controlling the voltage and either the power factor or VAR export of the generator and allow for "bumpless" transfer from one mode to another.

• **2.5.1.5** When specified for motors, the exciter field shall be supplied from a constant voltage transformer, a phase controlled rectifier, or other approved means to maintain 95 % of rated voltage or better for at least two seconds when the primary supply voltage drops to as low as 50 % of normal voltage.

2.5.1.6 Where excitation system control components that are sensitive to voltage disturbances are supplied, such as a programmable logic controller, power factor controller, etc., the method of supplying a secure voltage source for these components shall be jointly developed between the vendor and the purchaser.

2.5.2 Stationary Section

2.5.2.1 There shall be a maximum of 2 wires under any terminal in the excitation panel. If a 2 wire lug is used the lug shall have the appropriate size range for the conductors and be approved (labeled or listed) for the service. Where connections are made to box type compression terminals and wire sizes are 0.9 mm^2 (# 18 AWG) and smaller, crimp type pin terminals shall be used.

2.5.2.2 Analog signal wires shall be twisted pairs and routed or shielded to minimize interference from power conductors. All other classes of service shall be grouped together by service and voltage and physically isolated from each other.

2.5.2.3 The exciter stator winding shall meet the requirements of 2.3.1.5 and if applicable, 2.3.1.6. It shall be sufficiently insulated to tolerate the voltage transients and common mode voltages from the selected excitation control power module. If the excitation control power module is not included in the electrical machine manufacturer's scope of supply and no transient voltage levels are otherwise defined, the following voltage levels shall apply. The exciter stator windings shall be sufficiently insulated to tolerate input from a solid state chopper with 0.1 μs voltage rise times and common mode voltages equal to two times the line-to-line voltage.

2.5.2.4 The exciter stator windings shall be rated for the fundamental and harmonic currents produced by the selected excitation control power module

2.5.2.5 Appropriately rated, panel mounted surge protection shall be applied on the power input of the exciter control panel to protect components from lightning and switching transients.

2.5.3 Rotating Section

2.5.3.1 Conductors shall be fixed firmly to withstand centrifugal forces at the overspeed condition specified in 2.1.5.

2.5.3.2 Exciter rotor windings shall meet the requirements of 2.3.1.5 and if applicable, 2.3.1.6. They shall be insulated sufficiently to withstand any transients arising from the recovery of the diodes in the rotating rectifier.

• **2.5.3.3** When specified, rotating element mounted electronic components (including finished circuit boards, diodes, thyristors, etc.) shall be "burned in" for at least 48 hours. During this "burn-in" period, the boards and modules shall be cycled through their normal function and application rating for four consecutive timed intervals of 12 hours each (48 hours total). Each interval shall provide one ambient and one 60 °C temperature cycle of 6 hours each. Boards and modules shall be power cycled at an interval of 45 min "ON" and 15 min "OFF" for the entire 48 hours. The test chamber shall maintain the desired temperature levels within ± 3 °C throughout the chamber. Components rated for intermittent duty are not required to operate continuously during this test but should function within their normal duty cycle rating.

2.5.3.4 Rotating rectifier commutation spikes shall be limited to less than 4 × the average output voltage. The rotating rectifier may be equipped with fast recovery diodes, R-C snubber circuits, or other means to limit commutation spikes to the required level.

2.5.3.5 The rotating rectifier shall be equipped with an overvoltage protection circuit (varistor or voltage gated thyristor) to discharge the full field current in the case of a pull out or other transient.

2.5.3.6 Rotating rectifier diodes shall have a voltage rating of at least 1200 volts, or twice the peak value of the maximum rotor induced voltage (at maximum speed and maximum exciter stator voltage), whichever is greater.

NOTE The rotor induced voltage used to satisfy this requirement can be limited by overvoltage suppression devices.

2.5.3.7 Rotating rectifier diodes shall be current rated and provided with heat sinks such that their junction temperature does not exceed 125 °C when the machine is at its maximum temperature (rated torque and maximum ambient) and the lowest operating speed.

• **2.5.3.8** When specified, the manufacturer shall provide a test device and means to easily connect to all rotating electronic devices that will test and simulate the action of all rotating field application and control devices.

2.5.3.9 Connections shall either be soldered or tightened and positively locked in position.

• **2.5.3.10** When specified, the vendor shall supply an online rotor monitoring system to provide data on rotating section thermal and electric parameters. With the proposal, the vendor shall provide a list of what parameters are monitored.

2.5.3.11 The rotating field discharge resistor or starting resistor shall be adequately braced to withstand the mechanical stresses caused by electromagnetic forces and rapid thermal expansion during start-up and the centrifugal forces under normal operating conditions. The selection of materials shall be based on the effects of high thermal stresses during the start-up conditions specified in 2.2.5.2, and the resistor surface temperature shall not exceed 150 °C during these starting conditions. The resistor thermal capacity shall meet any starting capability requirements that are defined for repeated starts and margins in excess of expected acceleration times specified in 2.2.5.2 and 2.2.5.4. The resistor shall be waterproof to protect against corrosion.

• **2.5.3.12** When specified on fixed speed applications, rotating diode failure detection shall be supplied.

• **2.5.3.13** When specified, a permanent magnet generator (PMG) shall be provided for the alternator exciter power supply.

3 Accessories

3.1 Terminal Boxes

• **3.1.1** Main terminal boxes shall be constructed of steel plate with a minimum thickness of $^1/_8$ in. (3.0 mm). Minimum dimensions and usable volumes shall not be less than those specified in NEMA MG1 Part 21 Type II or IEC 60072. Stand-off insulators shall be either porcelain or cycloaliphatic resin material. Electrical insulating materials shall be nonhygroscopic. When specified, larger boxes shall be provided for shielded or special cable terminations and other devices or increased cable bending radius allowance.

3.1.2 The terminal box for the main power lead terminations shall be capable of withstanding the pressure build-up resulting from a three phase fault of the specified MVA (one-half cycle after fault inception) for a duration of 0.1 sec. For motors fed from fused motor starters, the box withstand capability shall be coordinated with the I^2t (ampere-squared sec.) let-through energy specified on the data sheet. If a rupture disc is used to relieve pressure build-up, it shall not compromise the environmental rating of the box and the discharge from the pressure release shall be directed away from locations where personnel may be normally present.

3.1.3 For machines rated at 601 V and higher, accessory leads shall terminate in a terminal box or boxes separate from the machine's main power terminal box. However, secondary connections for current and potential transformers located in the terminal housing are permitted to terminate in the terminal housing if they are separated from power leads or buses by a suitable physical barrier to prevent accidental contact and are accessible without removal of the main terminal box door or cover. For machines rated at 600 V and lower, the termination of leads of accessory items that normally operate at 50 V root mean square or less shall be separated from other leads by a suitable physical barrier to prevent accidental contact or shall be terminated in a separate box.

• **3.1.4** Terminal boxes and auxiliary equipment enclosures shall be IP55 (NEMA 4) and suitable for the area classification shown on the data sheets. Terminal boxes shall be arranged and be suitable for conductor entry as specified on the datasheets. Each terminal box shall have a bolted, gasketed cover that is arranged for convenient front access. (Explosion proof boxes shall not be gasketed unless specifically approved by the purchaser and approved for the application). Each terminal box shall be equipped with a breather/drain fitting. All auxiliary device wires shall be terminated on 600 V rated moisture resistant terminal blocks. All vertical covers or doors having gasketed surfaces shall be provided with a drip shield at the top. The gasket material shall be impervious to attack by the specified lube oil or other chemicals noted on the data sheet. Type test and or design information shall be supplied when requested on identical gasket material to verify that this requirement has been satisfied.

3.1.5 Grounding for field wiring inside the terminal box shall conform to the requirements of NEMA MG 1 Part 4 or IEC 60072.

• **3.1.6** When specified, the main terminal box shall be supplied with the following items:

a) thermal insulation on the interior top side;

b) space heaters in accordance with 3.4.2;

c) provisions for purging;

d) removable links;

e) adequate space for termination of shielded cables;

f) quick disconnect type bushings or receptacles;

g) arresters and surge capacitors (not applicable with ASDs);

h) differential and phase current transformers;

i) copper bus with silver or tin-plated bus connections;

j) potential transformers;

k) copper ground bus;

l) partial discharge sensors; and

m) insulated terminations and interior jumpers.

3.1.7 When surge protection is provided in accordance with 3.6.2, a low-impedance ground path shall be provided between the surge protection and the stator core. This low-impedance path shall be provided by running a copper conductor in parallel with the machine leads. The minimum conductor size shall be 107 mm^2 (4/0 AWG). This wire shall be as short as possible, and have only gradual bends with a minimum bending radius greater than 10 cable diameters (where practical), and bond the stator core to the terminal box by means of compression fittings at the ground point, as specified in 3.1.5.

• **3.1.8** When differential current transformers in accordance with 3.6.3 are specified, the leads shall be routed, in a workmanlike manner, away from high-voltage motor leads and protected by a physical barrier to prevent accidental contact. These leads shall be terminated at an appropriate shorting and grounding terminal block housed in an auxiliary box. The auxiliary box shall be accessible without removal of the main terminal box's cover. When self-balancing current transformers are furnished, both ends of each stator winding shall be brought out to the terminal box, and removable links shall be used to allow access to each end of the phase windings. Each link shall be installed so that it can be removed without disturbing other parts and connections.

3.1.9 Wiring and terminal blocks in all terminal boxes shall be clearly identified. The method for marking the wiring shall be a stamped sleeve of the heat-shrinkable type. The terminal blocks shall be permanently and suitably labeled. Stator leads shall be identified in accordance with NEMA MG 1 or IEC 60034-8. Current transformer leads shall have polarity identification markings at the transformer and at the terminal block in the auxiliary terminal box. All wire markings shall agree with the notations on the special nameplates required by 2.4.11.3.

3.1.10 All wiring shall have insulation that is suitable for the operating conditions specified in 2.1.2, and impervious to the lubricating oil specified.

• **3.1.11** Terminal heads or boxes, as specified, shall be supplied for bearing temperature detectors and the bearing-vibration sensing units.

3.2 Winding Temperature Detectors

3.2.1 Stator winding resistance temperature detectors (RTDs) shall be supplied.

3.2.1.1 Unless otherwise specified, RTD elements shall be platinum, three-wire elements with a resistance of 100 ohms at 0 °C (32 °F) per EN 60751, Class B. These elements shall have tetrafluoroethylene-insulated, stranded, tinned copper wire leads with cross sections at least equal to 0.4 mm^2 (22 AWG) in size. The leads shall meet the requirements of NFPA 70 or IEC 60079.

• **3.2.1.2** A minimum of three sensing elements per phase shall be installed, suitably distributed around the circumference in the stator winding slots. When specified one lead of each of these elements shall be grounded in the terminal box.

3.2.2 To prevent damage, the leads for all detectors shall be protected during manufacture and shipment. The vendor's drawings shall show the location and number of each sensing element in the stator winding and its connection point on the terminal strip.

• 3.3 Bearing Temperature Detectors

3.3.1 Bearing temperature detectors shall be provided in machines with hydrodynamic radial and thrust bearings. Detectors shall be installed so that they measure bearing metal temperature. Bearing temperature detectors shall be installed in such a way that they do not violate the integrity of the bearing insulation. Unless otherwise specified, RTD elements shall be platinum, three-wire elements with a resistance of 100 ohms at 0 °C (32 °F) per EN 60751, Class B.

These elements shall have tetrafluoroethylene-insulated, stranded, tinned copper wire leads with cross sections at least equal to 0.4 mm^2 (22 AWG) in size. The leads shall meet the requirements of NFPA 70 or IEC 60079. When specified, bearing temperature sensors shall be provided in accordance with API 670.

NOTE 1 Adoption of API 670 requires two sensors per bearing for most bearings.

NOTE 2 If two temperature detectors are required, the use of dual element sensors should be considered where space is limited.

3.4 Space Heaters

• **3.4.1** When specified, machines shall be equipped with completely wired space heaters that use high temperature insulation leads (such as silicone insulation) brought out to a separate terminal box. Heaters with exposed elements are prohibited. The heaters' sheath material shall be as specified. The heaters shall be installed inside the enclosure in a location suitable for easy removal and replacement. Heaters shall be located and insulated so that they do not damage components or finish.

• **3.4.2** Space heaters shall be low power density, single or three phase, with a frequency and voltage as specified, and with all energized parts covered. Low dissipation space heaters shall be provided and completely wired using high temperature insulation lead material of types FEPB, NI, and SA. Unless otherwise specified, surface temperatures of an unlabeled heating element shall not exceed 160 °C (320 °F). Unless otherwise specified, labeled heating elements shall be identified with a temperature code of T3 or lower temperature. The wiring shall be brought out to a separate terminal box. The heaters shall be installed inside the enclosure in a location suitable for easy removal and replacement. Heaters shall be located and insulated so that they do not damage components or finish. Any type of heater that contacts the surface of the stator winding is not acceptable.

3.4.3 Space heaters shall be arranged so that heat is radiated from both sides to provide uniform heating of the stator windings. The heaters shall maintain the temperature of the motor windings at approximately 5 °C (9 °F) above the ambient temperature.

3.5 Screens and Filters

3.5.1 When airflow inlet and outlet screens are provided, see 2.4.10.5 for material.

• **3.5.2** When specified, provisions for future airflow inlet filters in standard types and sizes shall be provided for open drip proof and Weather Protected Type I (IP23) enclosures. Filter requirements are to be in accordance with 3.5.4.

3.5.3 Airflow inlet filters in standard types and sizes shall be furnished in all machines having a Weather Protected Type II enclosure. Filter requirements are to be in accordance with 3.5.4.

• **3.5.4** When filters are specified, they shall be of the permanent type and shall meet the service requirements indicated on the datasheets. Filters shall be selected to remove 90 % of particulates 10 μm and larger or as specified on the datasheet. Entire filter element and assembly shall be constructed of AISI 300 series stainless steel.

• **3.5.5** When filters or provisions for future filters are provided, connections shall be furnished for a specified switch or gauge to measure the pressure drop across the filters.

3.5.6 Air filters shall be designed to permit easy removal and replacement while the machine is running.

3.6 Alarms and Control Devices for Machine Protection

• 3.6.1 Switches

Alarm and control devices shall be equipped with single-pole, double-throw switches with a minimum rated capacity of 10 amperes at 115 volts and 60 or 50 Hz. When specified, the vendor shall supply devices with DC rated contacts. The purchaser shall approve all devices.

3.6.2 Surge Protection

• **3.6.2.1** When specified, surge capacitors shall be furnished. The surge capacitors shall be the last devices connected to the leads before the leads enter the stator. When partial discharge capacitive couplers are used, the couplers shall be the last device before the leads enter the stator.

• **3.6.2.2** When specified, metal-oxide surge arresters shall be furnished and shall be installed in the terminal box.

3.6.2.3 The connection leads to the capacitors and arresters shall be at least 107 mm^2 (4/0 AWG). Leads shall have only gradual bends, if any, and shall be as short as possible with the total lead length (line-side and ground-side combined) on each capacitor and arrester not to exceed 0.6 m (2 ft) The surge arresters shall be rated for the system voltage and the method of system grounding specified on the data sheets (see 3.1.7 for bonding requirements).

• 3.6.3 Differential Current Transformers

When specified, differential-protection current transformers shall be provided. The purchaser will advise the vendor of the size, type, and accuracy class of the current transformers (see 3.1.8 for installation requirements).

• 3.6.4 Partial Discharge Detectors

3.6.4.1 When specified, the vendor shall supply and install stator winding partial discharge monitoring equipment. The make and type shall be as specified by the purchaser in the Data Sheets. The installed system will include sensing transducers, signal cables, interface equipment, termination devices, wiring, power supplies and terminal boxes as required to provide a complete system. The system output shall be either raw signals, relay contacts or processed data as appropriate to the particular system.

3.6.4.2 The sensing devices shall be mounted either in the main terminal box or in the stator windings, as required by the particular system. Sensing devices which are energized at line potential shall be subjected to a minimum of 30 kV rms for 1 min (for devices used on machines rated above 6.9 kV) and at a minimum of 15 kV for 1 min for machines rated 6.9 kV or less. Each device shall also be tested to have a partial discharge extinction voltage above 120 % of machine rated voltage with 5 pC sensitivity. The partial discharge test of the sensors shall be in accordance with ASTM D1868 or IEC 60270. All wiring from the sensors shall be routed along a conductive grounded metal surface inside the machine and in rigid metallic conduit external to the machine.

3.6.4.3 The coupling system shall be installed and wired in accordance with the system manufacturer's recommendations and terminated in a terminal box. The terminal box shall be mounted at an easily accessible location on an outside vertical surface of the main terminal box, unless otherwise specified. The box shall contain either the output terminals from the sensors or the output device supplied by the system vendor. Output terminals shall be permanently identified. If the system requires an external power supply the vendor shall supply terminals in the output terminal box for that power supply. Terminal boxes shall be grounded with a separate 16mm^2 (#6 AWG) or larger copper wire and shall meet the requirements of 3.1.5 of this standard.

3.6.5 Synchronizing and Control Devices

3.6.5.1 The vendor shall provide the necessary rectification devices between the exciter's AC output and the main field. The method of field application and synchronization shall be described by the vendor in the proposal and shall be jointly agreed upon by the purchaser and the vendor.

• **3.6.5.2** When specified, a freestanding control panel shall be supplied for mounting the control and protective devices listed on the accessory equipment section of the data sheet. As an alternative to this, individual components shall be supplied as indicated on the section of the data sheet for mounting and wiring by others.

3.7 Ground Connectors

Visible ground pads, made from corrosion resistant material, shall be provided at opposite corners of the machine frame. A ground connection point shall be provided by drilling and tapping the frame for a 12.0-mm ($^{1}/_{2}$-in. NC) thread bolt.

3.8 Vibration Detectors

• **3.8.1** Hydrodynamic bearing machines intended to operate at speeds greater than or equal to 1200 revolutions per min., or when specified for other speeds, shall be equipped with non-contacting vibration probes and a phase-reference probe, or shall have provisions for the installation of these probes. Non-contacting vibration probes and phase-reference probes shall be installed in accordance with API 670. Shaft surface preparation in the probe area shall be in accordance with 2.4.5.1.7.

3.8.1.1 The leads of the non-contacting vibration probes shall be physically protected by the use of conduit, or other purchaser specified means and shall be secured to prevent movement.

3.8.1.2 Oscillator-demodulators shall be mounted in a single dedicated junction box directly on the motor frame.

• **3.8.2** When specified, machines with hydrodynamic bearings shall have provisions for the mounting of four radial-vibration probes in each bearing housing, and where hydrodynamic thrust bearings are provided, they shall have provisions for two axial-position probes at the thrust end.

NOTE When the probes cannot be accessed during operation and the machine cannot be stopped conveniently to change defective probes, four probes at each bearing are recommended. Two of the probes are connected to the oscillator-demodulators and the other two probes have their leads run to the oscillator-demodulator terminal box and are not connected, but held as spares.

• **3.8.3** When specified, seismic vibration sensors, or provisions for such, shall be supplied in accordance with API 670.

NOTE 1 Axial-position probes are normally applied to monitor thrust-loading and hydrodynamic thrust-bearing conditions in vertical machines. Axial probes are occasionally used to monitor a rotor's axial vibration. On horizontal machines, axial probes should not generally be applied because no thrust bearing is present and because axial probes used as vibration sensors will not generally accommodate the rotor's relatively large amount of axial motion. Non contacting vibration systems are generally used on high-speed machines with hydrodynamic radial bearings, and accelerometer systems are generally used on units with antifriction bearings, which have high transmissibility of shaft-to-bearing force.

NOTE 2 Vibration detectors are not normally used on machines with 14 or more poles.

3.9 Wiring Methods

3.9.1 Except as noted in 3.9.2, all accessory wiring outside the motor enclosure and junction boxes shall be run in rigid metal conduit or other purchaser specified means.

3.9.2 Liquid tight flexible metal conduit may be used as the adjacent component to connect to the auxiliary device to facilitate the installation, maintenance or removal of auxiliary devices. Where liquid tight flexible metal conduit is used, the length shall be less than 0.9 m (3 ft).

3.9.3 Conduit and cable entrances to auxiliary terminal boxes shall be in the back, bottom or sides of the terminal boxes. Entrances to boxes shall be through threaded openings or by use of suitable weather-tight hubs or cable glands. Low points in conduit systems shall be equipped with drain fittings to prevent accumulation of condensation. Fittings shall be suitable for the area classification.

4 Inspection, Testing, and Preparation for Shipment

4.1 General

• **4.1.1** Whenever the specification or purchase order calls for shop inspections and tests to be witnessed, observed, or performed by a purchaser's representative, the vendor shall provide sufficient advance notice to the purchaser before each inspection or test. At all other times the purchaser's representative, upon providing similar advance notice to the vendor, shall have access to all vendor and subvendor plants where work on or testing of the equipment is in progress. In each instance, the actual number of calendar days considered to be sufficient advance notice shall be established by mutual agreement between the purchaser and the vendor.

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

• **4.1.3** The purchaser will specify the extent of his participation in the inspection and testing.

4.1.3.1 *Witnessed* means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or his representative in attendance. For vibration, unbalance response, and heat run tests, this requires confirmation of the successful completion of a preliminary test.

4.1.3.2 *Observed* means that the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his representative is not present, the vendor shall proceed to the next step.

4.1.3.3 *Required* means that the paragraph in question applies or that certified documentation shall be recorded for the purchaser.

4.1.4 Unless otherwise specified, all required test and inspection equipment shall be provided by the vendor.

4.2 Inspection

4.2.1 General

4.2.1.1 The vendor shall keep the following data available for at least 5 years for examination by the purchaser or his representative upon request:

a) certification of materials, such as mill test reports on shafts, forgings, and major castings;

b) purchase specifications for all items on bills of materials;

c) test data to verify that the requirements of the specification have been met;

d) results of all quality-control tests and inspections; and

• e) when specified, final assembly clearances of rotating parts (e.g. air gap, bearing and seal clearances).

4.2.1.2 Pressure containing parts shall not be painted until the specified inspection and testing of the parts is complete.

4.2.2 Material Inspection

• 4.2.2.1 General

When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 4.2.2.2 through 4.2.2.5 shall apply unless other corresponding procedures and acceptance criteria have been specified. Cast iron may be inspected in accordance with 4.2.2.4 and/or 4.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 4.2.2.2 through 4.2.2.5. Regardless of the generalized limits in 4.2.2, it shall be the vendor's responsibility to review the design limits of the equipment in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in 4.2.2 shall be removed to meet the quality standards cited, as determined by the inspection method specified.

4.2.2.2 Radiography

4.2.2.2.1 Radiography shall be in accordance with ASTM E94 or ISO 5579 and ASTM E142 or ISO 1027.

4.2.2.2.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-51 (continuous weld) and UW-52 (spot weld), of the ANSI/ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ANSI/ASME Code.

4.2.2.3 Ultrasonic Inspection

4.2.2.3.1 Ultrasonic inspection shall be in accordance with Section V, Articles 5 and 23, of the ANSI/ASME Code.

4.2.2.3.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-51 (continuous weld) and UW-52 (spot weld), of the ANSI/ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ANSI/ASME Code.

4.2.2.4 Magnetic Particle Inspection

4.2.2.4.1 Both wet and dry methods and magnetic particle inspection shall be in accordance with ASTM E709.

4.2.2.4.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 6, and Section V, Article 25, of the ANSI/ASME Code. The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 6.

Table 6—Maximum Severity of Defects in Castings

Type	Degree
I	1
II	2
II	2
IV	1
V	1
VI	1

4.2.2.5 Liquid Penetrant Inspection

4.2.2.5.1 Liquid penetrant inspection shall be in accordance with Section V, Article 6, of the ANSI/ASME Code or ISO 3452 and ISO 3453.

4.2.2.5.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 8, and Section V, Art. 24 of the ANSI/ASME Code.

4.2.2.6 Hydrostatic Testing

4.2.2.6.1 Pressure containing parts of water cooling circuits (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1 $^{1}/_{2}$ times the maximum allowable working pressure but not less than 138 kPa (20 lb per in.^{2}) gauge.

4.2.2.6.2 The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage is observed for a minimum of 30 min.

4.2.3 Inspection

4.2.3.1 During assembly of the lubrication system and before testing, each component (including 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.

• **4.2.3.2** When specified for machines having circulating pressure oil systems with a rated pump capacity of 5 gallons per min. or more, the oil system furnished shall meet the cleanliness requirements of API 614.

• **4.2.3.3** When specified, before final assembly the purchaser may inspect for cleanliness the equipment and all piping and appurtenances furnished by or through the vendor.

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

• 4.3 Final Testing

4.3.1 General

• **4.3.1.1** The purchaser reserves the right to observe the testing, dismantling, inspection, and reassembly of equipment, as specified.

4.3.1.2 The vendor shall notify the purchaser not less than 5 working days before the date that 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.

4.3.1.3 The vendor shall provide calculated data from final witnessed testing immediately upon completion of testing. The final results of critical parameters must be determined prior to the inspector leaving the test facility.

4.3.1.4 Tests shall be made on the fully assembled machine, using contract components, instrumentation, and accessories.

● **4.3.1.5** When specified, at least 6 weeks before the first scheduled test, the vendor shall submit to the purchaser, for his review and comment, detailed procedures for all tests, including acceptance criteria for all monitored parameters. The following items shall be included in the test procedures.

a) Types of tests (electrical or mechanical).

b) Testing sequence.

c) Detailed testing schedule.

d) Guarantee limits such as overall and filtered vibration levels; frequency and amplification factors of critical speeds; efficiency; noise levels; and stator, rotor, and exciter temperature rises.

e) Data measurements to confirm guarantee limits and proper operation of equipment components. This should include, but not be limited to, the following:

  1) power, voltage, current, power factor, full load speed, and torque;

  2) shaft and bearing vibration, unfiltered and filtered, and 1x phase angle for each probe;

  3) journal bearing embedded temperatures;

  4) stator winding temperatures;

  5) cooling water flow and temperature;

  6) temperature on air inlets and discharge;

  7) lube oil flows, pressures, inlet and drain temperatures for each bearing; and

  8) all instrumentation and data points which are to be monitored in the field.

f) Calculated lateral critical speed analysis.

g) A complete set of test data sheets which are to be used during the testing.

h) A listing of all alarm and shutdown levels.

i) Calibration sheets for all switches, vibration probes, and proximitors.

j) General arrangement drawings.

k) Residual rotor unbalance worksheet.

l) List of electrical test instrumentation and method of calibration.

m) List of the test equipment and data acquisition systems, including vibration measuring equipment, that will be used during the testing and how and when it was calibrated (or the calibration schedule).

♦ n) For ASD driven units, the following test conditions shall be included:

  1) the fundamental frequency(ies) at which the tests are carried out; and

  2) measurement of the harmonic contents of the input and output voltage and current waveforms.

• **4.3.1.6** When specified for machines operating above 400 rpm, the prebalanced coupling half (including idling adapters) shall be used during the unbalanced response tests.

4.3.1.6.1 The coupling hub shall be mounted on the rotor along with any idler adapter or mass moment simulator at the completion of the final rotor balance. If the rotor unbalance exceeds the allowable unbalance limit (SI 6350 W/N or US 4W/N per plane) after the coupling is mounted, the vendor and the purchaser shall mutually agree on the cause of the excess unbalance and appropriate corrective action taken.

4.3.1.6.2 If it is not practical to install the coupling on the shaft in the balance machine, the coupling hub and any idler adapter or mass moment simulator shall be installed after machine assembly but before the unbalance response test. Before installing the coupling, the machine shall be properly installed on a massive foundation and run at a voltage suitable to maintain magnetic center until the bearing temperatures stabilize, and a complete set of vibration data recorded. With the coupling mounted, the test shall be repeated. All data shall be within the limits given in Figures 2, 3, 4, and 5. The magnitude of the vectorial change in the 1 × vibration on the shaft and bearing housings shall not exceed 10 % of the vibration limits given in Figure 2 through Figure 5. If the vibration change or amplitude exceeds the allowable limits, the vendor and purchaser shall mutually agree on the appropriate corrective action (see Note for 2.4.6.3.3).

4.3.1.7 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.

4.3.1.8 During the mechanical running tests (where vibration data is being collected), the lube oil inlet temperature shall be adjusted to the maximum specified operating temperature.

4.3.1.9 Test stand oil filtration shall be 10 μm nominal or less. Oil system cleanliness shall meet the requirements of API 614 or ISO 10438 before any test is started.

4.3.1.10 All detection, protective, and control devices (except differential current, neutral, and auxiliary power transformers; surge capacitors; and lightning arresters) shall be tested to verify satisfactory performance.

4.3.1.11 During the running tests, the mechanical operation of all equipment being tested and the operation of the test and purchased instrumentation shall be satisfactory.

4.3.1.12 If replacement or modification of bearings or seals or dismantling to replace or modify other parts is required to correct mechanical performance deficiencies, the mechanical vibration and unbalance response tests shall be repeated after these replacements or corrections are made.

4.3.1.13 Internal or external oil leakage from the machine or contract components shall not occur during the tests. Any violation of this condition requires termination of the test until the necessary correction is made. Additional testing sufficient to verify that the oil leak is corrected must then be performed.

4.3.1.14 The vendor shall maintain a complete, detailed log and plots of all final tests and shall submit the required number of copies to the purchaser. This information shall include, but not be limited to, data for electrical performance, winding temperatures, bearing temperatures, rotor balancing, critical speeds, vibration measurements taken over the operating speed range, and the vibration spectrums. A description of the test instrumentation and certified copies of the instrument calibrations shall be kept available for the purchaser's review.

4.3.1.15 All test results shall be certified by the vendor and transmitted to the purchaser in reproducible form. Any exceptions to the information specified in 4.3.1.14 shall be listed in the proposal.

• **4.3.1.16** When specified, before the start of testing, the manufacturer shall demonstrate the accuracy of his test equipment and/or automated data acquisition systems. The calibration and maximum deviation, from a recognized standard, at all phase angles and anticipated frequencies and harmonics, shall be demonstrated. A maximum deviation of no more than 1/2 %, including all voltage transformers, current transformers, test leads, shunts, voltage dividers, transducers, analog to digital converters and computers, etc., that are part of the test set-up, shall be demonstrated. Every element of the test equipment setup shall be included in the accuracy demonstration.

4.3.1.17 Prior to any mechanical running test, a check for “soft feet” shall be made. After the machine has been aligned, shimmed, and firmly secured to the test base, a dial indicator micrometer oriented in the vertical direction shall be attached at the mounting foot to be checked. The micrometer is then zeroed, the mounting bolt or bolts loosened at the foot and the change in micrometer reading noted. If the micrometer reading exceeds 0.025 mm (0.001 in.), the mounting requires cleaning or re-shimming. This soft foot check shall be performed at each mounting foot, with the other feet secured, until all micrometer change readings are less than 0.025 mm (0.001 in.). If there are intermediate bases, this check shall be performed at each interface between the machine and test floor.

4.3.1.18 During the shop running test of the assembled machine, vibration measurements shall be made with the machine properly shimmed and securely fastened to a massive foundation (see Note 1 to 2.4.6.1.2) or test floor stand. Elastic mounts are not permitted.

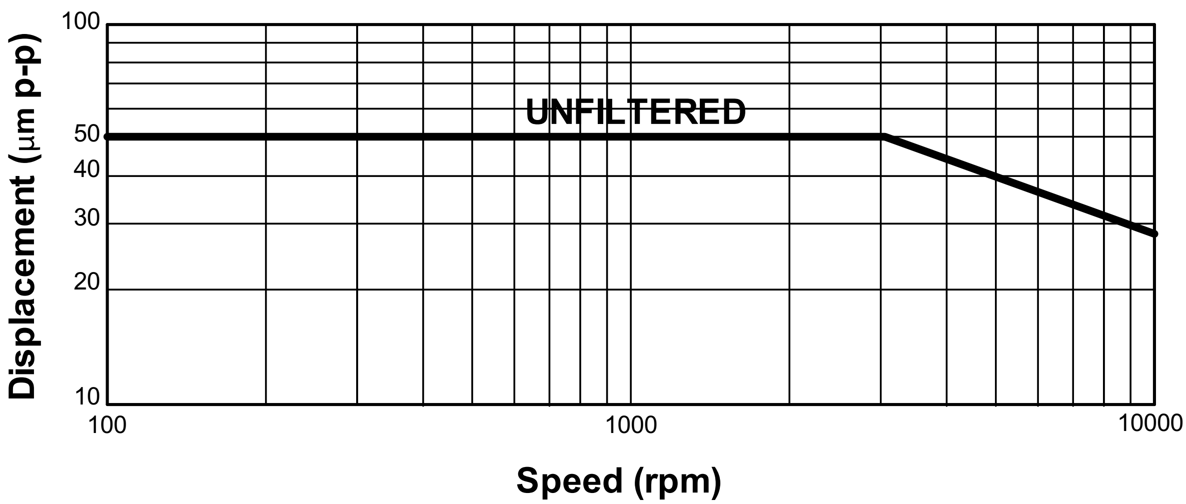


Figure 2—Shaft Vibration Limits (Metric Units, Relative to Bearing Housing Using Non-contact Vibration Probes) for All Hydrodynamic Sleeve Bearing Machines with the Machine Securely Fastened to a Massive Foundation

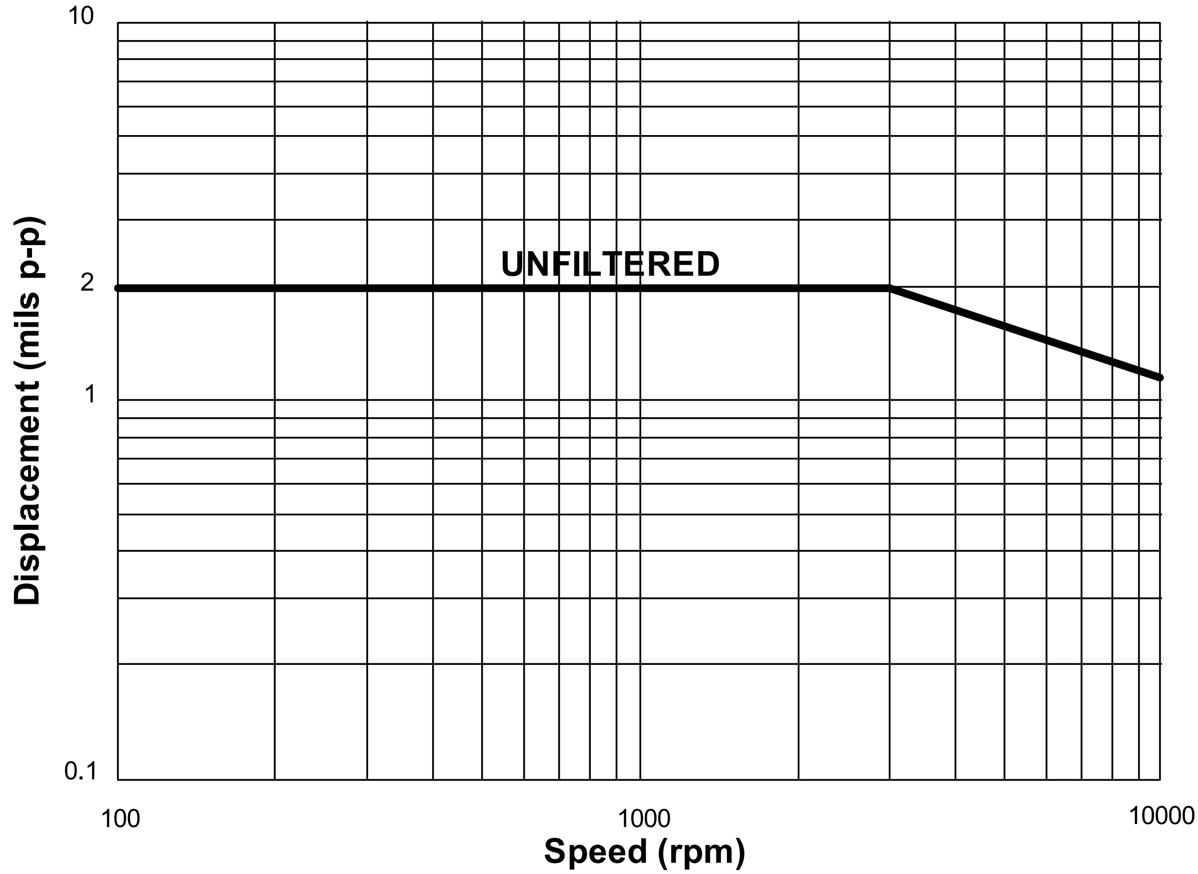


Figure 3—Shaft Vibration Limits (US Customary Units, Relative to Bearing Housing Using Non-contact Vibration Probes) for All Hydrodynamic Sleeve Bearing Machines with the Machine Securely Fastened to a Massive Foundation

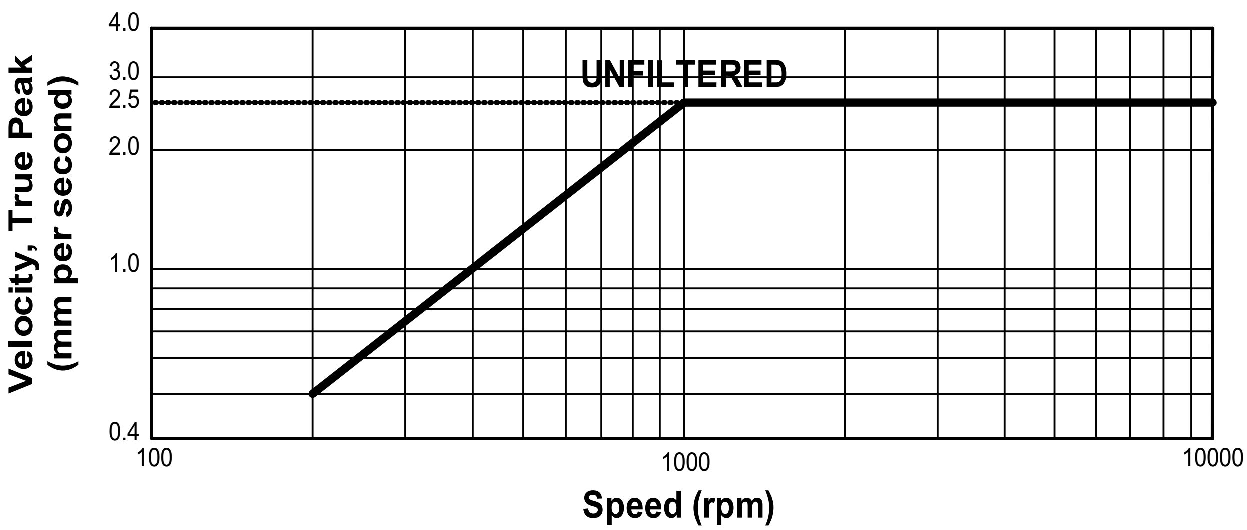


Figure 4—Bearing Housing Radial and Axial Vibration Limits (Metric Units) for Sleeve and Antifriction Bearing Machines with the Machine Securely Fastened to a Massive Foundation

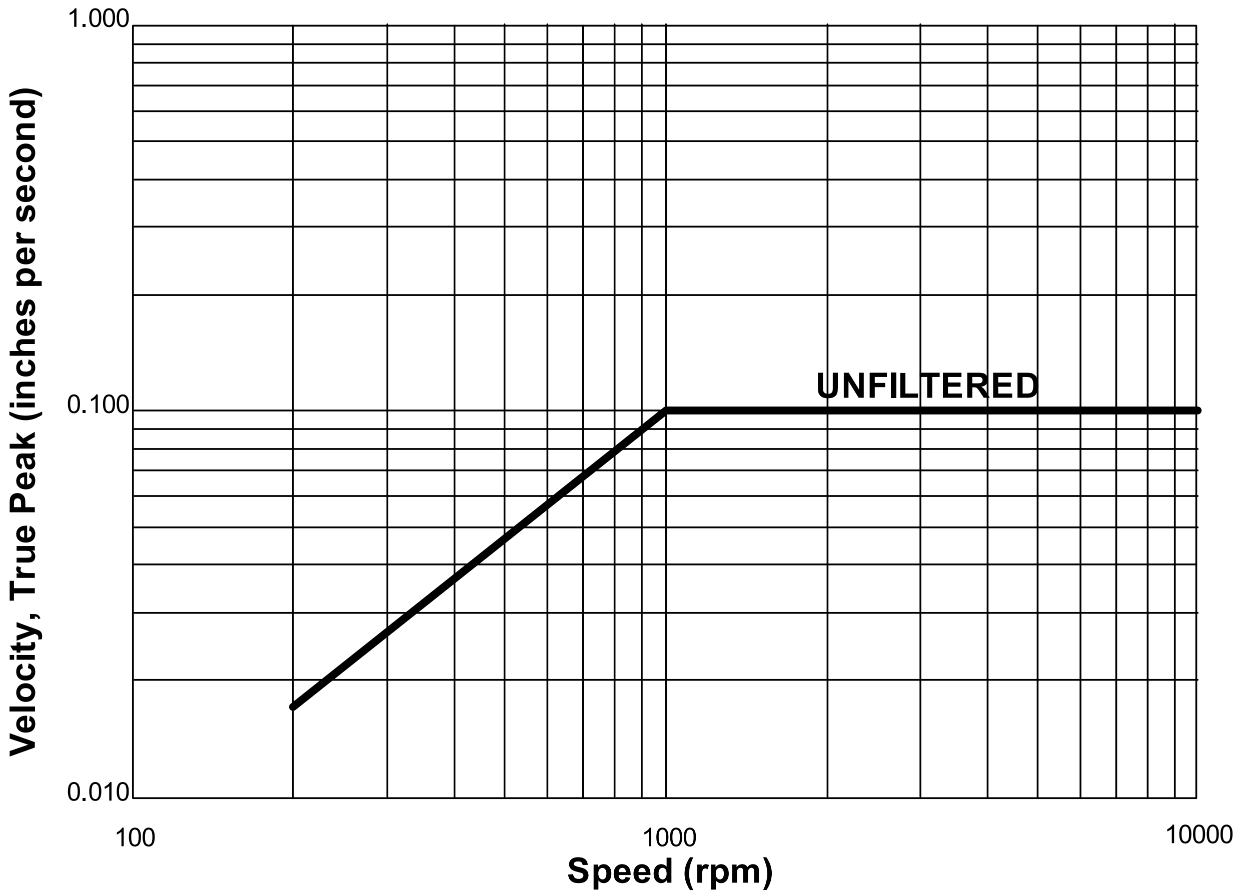


Figure 5—Bearing Housing Radial and Axial Vibration Limits (US Customary Units) for Sleeve and Antifriction Bearing Machines with the Machine Securely Fastened to a Massive Foundation

4.3.2 Routine Test

4.3.2.1 Each machine shall be given a routine test to demonstrate that it is free from mechanical and electrical defects. These tests shall be conducted in accordance with the applicable portions of NEMA MG 1 and IEEE 115, or IEC 60034-2 and 60034-4. The test shall include the following items:

a) Measurement of no-load current (each phase) and exciter field current.

b) A determination, by calculation, of locked-rotor current.

c) A high-potential test on the stator and field windings.

• d) An insulation resistance test by megohmmeter and polarization index per IEEE 43. The insulation resistance measurement and polarization index shall be performed in accordance with Table 7. (The polarization index is the ratio of the 10-minute resistance value to the 1-min resistance value.) The minimum acceptable value for the stator winding polarization index is 2. The stator winding polarization index values shall be determined both before and after the high-potential test of the stator winding.

NOTE If the 1 min insulation resistance is above 100 GΩ, the calculated polarization index may not be meaningful. In such cases, the polarization index may be disregarded as a measure of winding condition and the minimum acceptable value of 2.0 may not apply.

Table 7—DC Test Voltages for Insulation Resistance and Determination of Polarization Index

Motor Voltage	Test Voltage
< 2300	1000
2300–3999	2500
≥ 4000	5000

e) Measurement of stator and field winding resistance, using a digital low resistance meter.

f) Measurement of vibration (see 4.3.1.6 and 4.3.3).

g) A test of the bearing insulation.

h) A test of bearing temperature rise. The motor shall be operated at no-load for at least 1 hour after the bearing temperatures have stabilized. Stable temperature is defined as a change of not more than 1 °C in 30 min. The no-load run shall demonstrate that bearing operation is without excessive noise, heating, vibration, or lubrication leaks.

i) Inspection of the bearings and oil supply, when furnished. After all running tests have been completed, the shaft journals and bearings shall be inspected by completely removing both the top and bottom halves of each sleeve bearing. The contact between the shaft journal and the bearing bore shall be a minimum of 80 % of the axial length and symmetrical with no edge loading or metal transfer between the shaft and the bearing. Where the lubricant is accessible, its condition shall be visually examined after the run.

• j) When specified, before the tests are run, each bearing's journal-to-bearing clearance and bearing-shell-to-bearing-cap crush and alignment shall be determined and recorded.

• k) When specified, after the tests are run, each bearing's journal-to-bearing clearance shall be determined and recorded.

l) Measurements of the main machine and exciter air gaps. Allowable limits are per 2.4.7.2.4.

4.3.3 Vibration Tests

4.3.3.1 Electrical and mechanical runout shall be determined with the rotor supported at the bearing journal centers by lubricated v-blocks, lunettes (hydrodynamic bearing segments), or other non-damaging means of support. The rotor shall be rotated through the full 360 degrees while measuring runout with a non-contacting vibration probe and a dial indicator. Measurements shall be made at the centerline of each probe location and one probe tip diameter to either side. Alternative methods that determine out-of-roundness of the journal and track, concentricity between the journal and track, and electrical runout that achieve the above results are also acceptable. Measurements utilizing this method shall be taken at least every ten degrees of rotation. The acceptance criteria are specified in paragraph 2.4.5.1.7.

4.3.3.2 Accurate records of electrical and mechanical runout, for the full 360 degrees at each probe location, shall be included in the test report.

4.3.3.3 Electrical and mechanical runout shall also be measured in the assembled machine with the rotor at slow roll speed (200 to 300 rpm). The continuous unfiltered trace of the probe output shall be recorded for a 360 degree shaft rotation at each probe location. The rotor shall be held at its axial magnetic center during recording. The acceptance criteria for the combined total electrical and mechanical runout in the assembled machine shall not exceed 25 % of the allowed peak-to-peak unfiltered vibration amplitude. This runout data shall be used to compensate the shaft vibration readings filtered at running speed.

4.3.3.4 Vibration measurements shall be taken in the horizontal and vertical radial directions and the axial direction on the bearing housings. All shaft radial-vibration measurements shall be taken using non-contacting eddy-current probes when equipped with them or when provisions for non-contacting probes are specified. Where shaft non-contacting probes or provisions for probes are not specified, only bearing-housing vibration measurements are required. (See 2.4.5.1.7 for requirements at probe sensing areas.) Shaft and bearing housing vibration data shall be recorded for unfiltered amplitudes and for filtered amplitudes at one half running speed, one times running speed (including phase angle), two times running speed, and one and two times line frequency.

4.3.3.5 Unfiltered and filtered radial and axial vibration, electrical input, and temperature data shall be recorded at 30 min intervals during all mechanical running tests. If the vibration pulsates, the high and low values shall be recorded.

- **4.3.3.6** When specified, if mutually agreed upon by the purchaser and the vendor, the purchaser may use his monitoring or recording equipment in conjunction with the vibration transducers mounted on the machine to record the dynamic behavior of the machine during testing.

4.3.3.7 All purchased vibration probes, transducers, 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.

4.3.3.8 Shop test facilities shall include a computer based data acquisition and reduction system with the capability of continuously monitoring, displaying, and plotting required unfiltered and filtered vibration data to include revolutions per minute, peak-to-peak displacement, phase angle, and zero-to-peak velocity. The data shall be submitted to the purchaser together with the final test report. In addition, an oscilloscope and spectrum analyzer shall be available.

4.3.3.9 The vibration characteristics determined by the use of the instrumentation specified in 4.3.3.4, 4.3.3.6, and 4.3.3.7 shall serve as a basis for acceptance or rejection of the machine.

- **4.3.3.10** During the shop test of machines with two or more bearings and while operating at rated voltage and rated speed or at any other voltage and speed within the specified operating speed range, the shaft displacement and bearing housing velocity of vibration shall not exceed the limits specified in 4.3.3.10.1 through 4.3.3.10.5. Values for single bearing machines shall be the same unless otherwise determined by agreement between the purchaser and vendor. If a temperature test is specified (see 4.3.5.1.1 d), the vibration shall be within the filtered and unfiltered limits specified in 4.3.3.10.1 through 4.3.3.10.5 throughout the temperature range from the test ambient temperature to the total design temperature. When specified, lower vibration limits shall apply as noted on the data sheets.

4.3.3.10.1 The unfiltered vibration limits for machines up to 3000 rpm rated speed shall not exceed 50 μm (2 mils) p-p displacement. For machines with rated speeds in excess of 3000 rpm, the unfiltered vibration limit shall not exceed:

In SI units:

$$A = 25\sqrt{\frac{12000}{N}} \quad \mu\text{m} \tag{7}$$

In Customary units:

$$A = \sqrt{\frac{12000}{N}} \quad \text{mils} \tag{8}$$

where

N is the maximum rated speed (rpm).

These shaft readings include a maximum allowance for electrical and mechanical runout in accordance with 4.3.3.1. The vibration limits are shown graphically in Figure 2 and Figure 3.

4.3.3.10.2 Shaft vibration displacement at any filtered frequency below running-speed frequency shall not exceed 2.5 μm (0.1 mil) or 20 % of the measured unfiltered vibration displacement, whichever is greater.

4.3.3.10.3 Shaft vibration displacement at any filtered frequency above running-speed frequency shall not exceed 12.5 μm (0.5 mil) p-p.

4.3.3.10.4 Shaft vibration displacement filtered at running speed frequency (runout compensated) shall not exceed 80 % of the unfiltered limit.

4.3.3.10.5 Bearing housing radial and axial velocity shall not exceed in total or at any individual frequency:

In SI units:

$$V = 0.0025 \times \text{rpm} \qquad \text{mm/s} \tag{9}$$

In Customary units:

$$V = 0.0001 \times \text{rpm} \qquad \text{in./s} \tag{10}$$

Or 2.5 mm/s (0.1 in./s) 0-p whichever is less.

The vibration limits are shown graphically in Figure 4 and Figure 5.

NOTE For total bearing housing radial or axial velocity limit, rpm = maximum rated speed. For individual vibration frequencies, convert the frequency in question to rpm, i.e. 120 Hz = 7200 rpm, 60 Hz = 3600 rpm.

4.3.3.11 The magnitude of the resultant vector (filtered 1 × vibration) change from no load to rated temperature shall not exceed 20 μm (0.80 mils) for shaft vibration and 1.25 mm/s (0.05 in./s) for the bearing housing vibration. Annex G outlines a procedure for determining the resultant vector change.

4.3.3.12 4.3.3.12 For motors which do not comply with the vibration vector change limits stated above, Annex G (Figure G.4) or 4.3.3.12.1 through 4.3.3.12.3 represent an alternate vibration acceptance criterion, which can be applied when specifically approved by the purchaser.

4.3.3.12.1 For motors which do not comply with the requirements stated in 4.3.3.11, while remaining within the limits in 4.3.3.10, the vendor shall repeat the temperature test of 4.3.3.

4.3.3.12.2 Prior to starting the repeat temperature test and again after completing the repeat temperature test, the motor must be cooled down to no load stabilized temperatures.

4.3.3.12.3 The magnitude of the resultant 1 × running speed vibration vector change between subsequent tests for the cold motor under no load and for the hot motor at rated temperature shall be within 10 % of the allowable limits in 4.3.3.10.

4.3.3.13 The magnitude of the unfiltered horizontal vibration of any loaded structural member of the frame along the axis of the shaft centerline shall not exceed two times the limit given in 4.3.3.10.5 when operating at no-load, full voltage, and rated frequency. Measurements shall be taken on the outside of the machine, at the loaded structural member of the frame. A loaded structural member of the frame is defined as one of the steel plates or structural sections that support the stator core in the case of box frames. For other designs, measurement points shall be agreed between the manufacturer and purchaser prior to the purchase order.

4.3.3.13.1 In small or medium size machines, all measurement points may not be accessible due to the location of conduit or accessory boxes that can block the required position of the sensor. In that case, if the location for the sensor on the opposite side of the motor is accessible, the frame vibration at the sensor location that is not accessible does not need to be measured. If neither sensor location is accessible, then the test must be conducted with conduit or accessory boxes removed as required to provide access for the measurement.

♦ **4.3.3.13.2** For ASD driven units, it may not be possible to guarantee the above value across the entire speed range due to local panel resonances that can be present and affect the overall value at the measurement points. For such cases, an acceptance value shall be agreed between the manufacturer and the purchaser prior to the purchase order, and the manufacturer must demonstrate that the frame has infinite fatigue life for the frequency where the peak vibration occurs.

4.3.3.14 While the equipment is operating at maximum continuous speed and a stable temperature, sweeps shall be made for vibration amplitudes at frequencies other than running speed. These sweeps shall cover a frequency range from 25 % of the running-speed frequency to four times the line frequency. Limits on individual frequency components are set in 4.3.3.10.1 through 4.3.3.10.5.

● **4.3.3.15** When specified, an electronic copy of the vibration data shall be provided in a format mutually agreed upon between the purchaser and vendor.

4.3.3.16 Trim balancing may be performed, if approved by the purchaser. The residual unbalance test (2.4.6.3.6 and Annex F) is required after trim balancing. Trim balancing shall not be used to compensate for thermal bow. Any balancing done after the start of testing shall void any prior vibration (4.3.3 and 4.3.5.3) or heat run (4.3.5.1.1 and 4.3.5.2.2) testing and these tests shall be repeated.

● **4.3.3.17** The vibration limits for motors driven by ASDs are the same as for fixed speed units. The limits shall be met at all supply frequencies in the operating speed range.

4.3.4 Stator Tests

● 4.3.4.1 Stator Core Test

When specified, prior to insertion of the stator coils into the core, the stator core interlaminar insulation integrity shall be verified. The test shall be performed by inducing rated flux density into the core by placing coils through it in a manner similar to a transformer winding. Rated flux shall be maintained for a minimum of one half hour while continuously monitoring stator temperatures with an infrared camera. There shall be no location (hot spots) on the stator core having a temperature greater than 5 °C (9 °F) above the adjacent core temperature.

4.3.4.2 Surge Test

Surge comparison tests shall be made of the turn insulation in the fully wound stator just before the coil-to-coil connections are made, at test levels and methods in accordance with Figure 1 of IEEE 522 or IEC 60034-15.

● **4.3.4.2.1** When specified, two additional stator coils for special surge tests of the main and turn insulation shall be manufactured at the same time as the complete stator winding. These coils shall be completely cured and tested as follows:

a) The test of the main insulation shall consist of three successive applications of a 1.2/50-microsecond impulse voltage with a crest value of 5 pu. The impulse voltage shall be applied to both terminals of the coil conductor while the conducting surfaces of the simulated slot portions of the coil are grounded.

b) The test of the turn insulation shall consist of successive applications within 1 min intervals of voltage impulses having a rise time of 0.1 to 0.2 microseconds applied between the coil terminations. The test voltages shall include values of 2.0, 3.5 and 5.0 pu. The crest value of the voltage impulse shall be gradually increased until the point of insulation failure is reached.

c) At the completion of the tests, the sacrificial coils shall be cut into segments as necessary for inspection.

d) If the coils fail at less than 5 PU, the cause shall be investigated and the impact to the main stator determined so that appropriate remedial measures can be agreed upon between the purchaser and vendor.

• 4.3.4.3 Power Factor Tip-up Test

When specified, a power factor tip-up (tan-delta) test shall be performed on the completely wound stator, in accordance with IEEE 286 or IEC 60894. The acceptance criteria shall be mutually agreed upon between the vendor and purchaser.

• 4.3.4.4 Sealed Winding Conformance Test

When specified, motor stators equipped with sealed insulation systems shall be tested in accordance with NEMA MG 1 Part 20 by means of a water-immersion or spray test. These tests shall be in addition to all other tests. At the completion of the water-immersion or spray test, the stators shall be rinsed and dried, at which point any other required tests may be performed. Any internal ionization or carbonization initiated during a failure of the test will weaken the insulation and must be repaired. If the winding fails the AC overpotential test upon the third attempt, the winding may be replaced at the purchaser's option.

NOTE This test exposes certain parts of the insulation to stress levels that are in excess of what it sees during normal operation.

• 4.3.4.5 Stator Inspection Prior to VPI

When specified, the fully wound and connected stator shall be inspected prior to VPI.

• 4.3.4.6 Partial Discharge Test

When specified for machines rated 4 kV and greater, an off-line partial discharge test shall be performed on the stator windings, in accordance with Clause 10.2 of IEEE Std 1434 or IEC TS60034-27. Where possible, the tests shall be performed on each phase individually with the other phases grounded. Test voltage shall be the greater of 4 kV or the operational phase to ground voltage, and the test voltage shall be maintained for at least 5 min conditioning time. As a minimum, partial discharge inception voltage (PDIV) and partial discharge extinction voltage (PDEV) shall be recorded for each phase as well as power supply frequency, temperature and humidity at the time of test. The acceptance criteria shall be mutually agreed upon between the vendor and purchaser prior to performing the tests.

NOTE 1 Partial discharge performance of insulation systems varies between manufacturers and specifying absolute levels is not presently considered appropriate. Of greater importance is that the performance of a particular machine's insulation system is consistent with the performance of similar systems from the same source. Significant variation in performance may be an indication of voids or other problems with the insulation.

NOTE 2 The performance of a particular machine's insulation system often improves after some time in service. Therefore comparison with site performance of existing machines may not be valid.

4.3.5 Special Tests

4.3.5.1 Complete Test

● **4.3.5.1.1** When specified, each machine shall be given the complete test described below, items a through g, in addition to the tests specified in 4.3.2. This test shall be in accordance with the applicable portions of IEEE 115 and NEMA MG 1 or IEC 60034-2 and 60034-4 and shall include the following items.

♦ a) Determination of efficiency at 100 %, 75 %, and 50 % of full load. The vendor shall indicate which method will be used in determining the performance data. Efficiency determination method and supply frequencies of motors on ASDs shall be determined by consultation between the purchaser and the vendor.

NOTE 1 Losses in a motor driven by an ASD may be significantly different compared to those when the motor is driven by a constant frequency sinusoidal source.

NOTE 2 Motors that are designed to be operated only on an ASD do not require tests b and f below. Also, the method for test d may require special consideration and should be jointly developed by the purchaser and vendor.

b) Determination of locked-rotor current, power factor, and mean torque, and a determination by calculation of pull-out torque as applicable.

c) Tests for the construction of the open-circuit saturation and core loss curve and for the short-circuit saturation and loss curve.

d) A heat run (temperature) test of the main armature and field at the maximum continuous rated service factor (using the zero-power-factor method or the synchronous feedback technique).

NOTE For larger machine sizes, a heat run test may be limited to only open-circuit and short-circuit tests.

e) An exciter heat run (temperature test in conjunction with the main machine test or certified data from a duplicate design).

f) Tests for the construction of the no-load V curve (stator current versus exciter field current curve at the machine's rated voltage).

g) Noise test in accordance with ANSI S12.54 or ISO 3744 with the machine operating at no load, full voltage, rated frequency, and sinusoidal power.

● **4.3.5.1.2** When specified, the motor's insulation will be tested by means of a DC high-potential test to the maximum voltage listed in Table 8. The test procedure shall be to apply voltage in not less than four approximately equal steps, pausing 1 minute at each step and 5 minutes at the final voltage, taking 15 seconds to increase the voltage slowly at the beginning of each step. During the test, a micro ammeter shall be watched closely for the inception of any leakage-current advance.

● **4.3.5.1.3** When started asynchronously, all four and six pole motors shall have tests performed to determine pulsating torques in accordance with IEEE 1255. When a torsional analysis is specified, this test shall be applied to slower speed motors.

4.3.5.2 Rated Rotor Temperature Vibration Test

● **4.3.5.2.1** When specified, for machines that do not receive the complete test of 4.3.5.1.1, a heat run test in accordance with 4.3.5.1.1, item d shall be performed.

Table 8—DC High-potential Test Voltage Levels

Motor Rated Voltage (KV) E	DC High-Potential Test Voltage (kV) (2E + 1)(0.75)(1.75)
2.3	7.4
2.4	7.6
4.0	11.8
4.16	12.2
6.6	18.6
6.9	19.4
13.2	36.0
13.8	37.5

4.3.5.2.2 If the heat run test specified in 4.3.5.1.1, item d cannot be performed due to test stand limitations, the vendor shall submit complete details of an alternative test that permits measurements of vibration throughout the test for at least 4 hours with the machine operating at rated speed and with the rotor reaching full-load temperature.

• 4.3.5.3 Unbalance Response Test

When specified, satisfactory dynamic performance (see 2.4.6.1.1) shall be verified by attaching the machine to a massive foundation support and subjecting the machine to the following unbalanced response test. Special considerations may be required for super-synchronous machines. For critical speed considerations, a test shall be made with a coupling-half mass moment or moments equivalent to those of the contract coupling or couplings.

a) A balanced coast down shall be performed with the machine in balanced state. The machine shall be run to 120 % of its rated speed then allowed to coast to rest. The shaft vibration and phase angle relative to the bearing housing and the bearing housing vibration shall be recorded for reference purposes.

b) A deliberate unbalance of $4Ub$ per plane [see 2.4.6.3.4, Equation (2) or Equation (3)] shall be applied to the rotor. The weights shall be placed at the balance planes in-phase to excite the first lateral critical speed. In cases where the 2nd or higher order lateral critical speeds may encroach on the running speed range separation margin, the test also shall be performed with the weights placed at the balance planes 180 degrees out-of-phase. In cases where an overhung mass is present, such as a fan or coupling, resulting in a bending mode with maximum deflections at the shaft end, the tests also shall be performed with unbalance weight placed on the coupling. The amount of unbalance to be added to the overhung mass shall be based on four times the allowable residual unbalance in the overhung mass. (For example, from API 671 the assembled coupling may be balanced to $40W_c/N$ where W_c is the weight of the coupling and N is the maximum continuous speed. In this case, the amount of unbalance to be added to the coupling would be $160W_o/N$ where W_o is the weight of the overhung mass.)

c) The tests can be performed with the unbalance weights placed at any location on the balance planes or coupling. Each test also shall be repeated with the weights moved to new positions 90 degrees from the original positions to determine the sensitivity of the rotor response to unbalance weight placement. The maximum response obtained shall be used as the acceptance criteria.

d) The machine shall be run to 120 % of its rated speed with the unbalance weights attached and then allowed to coast to rest. The shaft vibration relative to the bearing housing shall be observed. Machines shall meet the following criteria.

1) The shaft displacement relative to the bearing housing at any speed within the operating speed range or 15 % separation-margin limit shall not exceed the smaller of the following value or 55 % of the minimum design shaft-to-bearing and seal diametric running clearances:

In SI units:

$$D_S = 38\sqrt{\frac{12000}{N}} \tag{11}$$

In Customary units:

$$D_S = 1.5\sqrt{\frac{12000}{N}} \tag{12}$$

where

D_S is 1 × runout compensated shaft displacement, in μm (mils) peak-to-peak;

N is the operating speed nearest the resonant speed of concern, in revolutions per min.

2) The shaft displacement relative to the bearing housing at any speed outside the operating speed range or separation-margin limits shall not exceed 80 % of the minimum design shaft-to-bearing diametric running clearance.

e) For machines which do not comply with the separation margin of 2.4.6.1.1, and when specifically approved by the purchaser, a well-damped resonance (response) shall be demonstrated. The motor shall be run to 120 % of its rated speed with the unbalance weights attached as described in 4.3.5.3 a, 4.3.5.3 b and 4.3.5.3 c and then allowed to coast to rest. The shaft displacement over the entire speed range, from 0 % to 120 %, shall not exceed the following value:

In SI units:

$$D_S = 38\sqrt{\frac{12000}{N_{\mathrm{MAX}}}} \tag{13}$$

In Customary units:

$$D_S = 1.5\sqrt{\frac{12000}{N_{\mathrm{MAX}}}} \tag{14}$$

where

D_S is 1 × runout compensated shaft displacement, in μm (mils) peak-to-peak;

N_{max} is the maximum rated speed, in revolutions per min.

(Annex H outlines an alternate procedure to determine a well damped resonance.)

• 4.3.5.4 Bearing Housing Natural Frequency Test

4.3.5.4.1 When specified, bearing housings or end bell supports shall be checked for resonance on one fully assembled machine (see 4.3.1.4) of each group of identical machines. The resulting response shall be plotted for a frequency sweep of 0 % to 400 % of line frequency. In order to eliminate the interaction between the bearing housings, the rotor shall be turned at a slow roll (approximately 200 rpm to 300 rpm). The response plots shall be made on each bearing housing in the horizontal, vertical and axial directions. The application of the excitation force must be made in these same directions.

4.3.5.4.2 No significant resonance shall occur within plus or minus 15 % of one and two times running speed, plus or minus 15 % of one and two times line frequency, or between 40 % and 60 % of running speed as required by 2.4.2.1. A significant resonance is defined as a peak that lies within 6dB in amplitude (displacement) of the fundamental bearing housing resonance in the particular direction being tested. Percentages are based upon one times running speed and electric line frequency.

4.3.5.4.3 On adjustable speed machines, the vendor shall propose an alternate method in the proposal to verify that the natural frequency of the bearing housing will not be excited within the operating speed range. Purchaser must approve this method.

• **4.3.5.5 Heat Exchanger Performance Verification Test**

When specified for machines with TEWAC heat exchangers, the performance of the heat exchanger shall be demonstrated. The test shall be conducted during a heat run of at least four hours with the cooling water flow and temperature maintained as close as practical to rated conditions while the machine is operating as close as practical to rated voltage, current, and frequency. During this test, all pertinent mechanical, electrical, temperature, and flow rate data shall be recorded. The heat exchanger air outlet temperature shall not exceed the specified value, usually 40 °C. If the heat exchanger test at rated conditions is not possible due to either the machine size or the test facility capabilities, the vendor and purchaser shall jointly develop a test method to satisfactorily demonstrate the heat exchanger performance.

NOTE If a complete test is specified, this heat exchanger test may be performed in conjunction with the heat run required as part of the complete test.

4.4 Preparation for Shipment

• **4.4.1** Each unit shall be suitably prepared for the type and mode of shipment specified. Preparation for shipment shall be performed after all testing and inspection have been completed and the purchaser has released the equipment for shipment. When specified, preparation shall make the equipment suitable for at least 6 months of outdoor storage from the time of shipment and shall include items a) through l) below (as required). 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 before start-up. One copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

a) Exterior surfaces, except for machined surfaces or corrosion resistant material, shall be coated with manufacturer's standard paint. Exposed shafts and shaft couplings shall be wrapped with an easily removed waterproof coating or wrapping. Bearing assemblies shall be fully protected from the entry of moisture and dirt.

b) After thorough cleaning, internal areas of bearings and auxiliary equipment for carbon steel oil systems shall be coated with a suitable oil-soluble rust preventive.

c) For shipping purposes, flanged openings shall be provided with metal closures at least 5.0 mm ($^3/_{16}$ in.) thick, with synthetic rubber gaskets and at least four full-diameter bolts.

d) For shipping purposes, threaded openings shall be provided with steel caps or solid-shank steel plugs. Nonmetallic threaded plugs may only be used for terminal box openings.

e) The equipment shall be mounted on a rigid skid or base suitable for handling by forklift, truck or crane. This skid shall extend beyond all surfaces of the machine.

f) Lifting points and lifting lugs shall be clearly marked. Each machine shall be properly identified with item and serial numbers. Material shipped in separate crates shall be suitably identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. The recommended lifting arrangement shall be identified on boxed equipment.

g) If vapor-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags must be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers, and corrosion-resistant tags attached with stainless steel wire shall indicate bag locations.

h) The fit-up and assembly of machine-mounted piping, coolers and other equipment shall be completed in the vendor's shop before shipping, unless specifically approved otherwise by the purchaser. 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. Components (both individual pieces and packaged sets) shipped with mounted preassembled piping, tubing, or wiring shall comply with the requirements of the Occupational Safety and Health Administration.

i) Machines that are disassembled for shipment or storage shall be provided with marine type plywood over all openings and sloped for proper watershed when protected with exterior covering.

j) The rotor shall be blocked to prevent axial and radial movement.

k) When required by machine size, configuration or method of transportation, the normal running bearings shall be removed and shipped in protective crates, and the machine shall be equipped with special bearings for shipment.

l) Space-heater leads shall be accessible without disturbing the shipping package and shall be suitably tagged for easy identification.

5 Guarantee and Warranty

The details of the guarantee and warranty will be developed jointly by the purchaser and vendor subsequent to submission of the proposal, and supporting documentation included in the contract documents.

6 Vendor's Data, Drawings and Manuals

6.1 Coordination Responsibility

The vendor shall be responsible for providing the purchaser with all details necessary for proposal evaluation, contract performance, and installation, operation, and maintenance of the machine as an integral part of the complete unit assembly.

6.2 Proposals

Vendor's proposals shall provide the information specified in this section and include completed "Vendor's Sections" of the motor or generator data sheets in Annex A or Annex B. These data sheets shall be marked "Applicable for Proposal" on Line 5 of Sheet 1.

• **6.2.1** When the evaluation factor (dollars per kilowatt) is shown on the data sheets, machines will be evaluated on the basis of life-cycle cost (purchase price plus present worth of losses).

6.2.2 The vendor shall provide complete performance curves and data to fully define the envelope of operation and the point at which the manufacturer has rated the equipment, including the following items:

6.2.2.1 *For motors*.

• a) Average torque and twice slip frequency pulsating torque versus speed during starting at rated voltage and minimum starting conditions (voltage and/or short circuit MVA) and any other specified conditions.

• b) Current versus speed during starting at rated voltage and minimum starting conditions (voltage and/or short circuit MVA) and any other specified conditions

c) The inertia of the rotor.

• d) Estimated times for acceleration at rated voltage and minimum starting conditions (voltage and/or short circuit MVA) and any other specified conditions.

• e) The locked-rotor (stalled) withstand time, with the motor at ambient temperature and at its maximum rated operating temperature, at rated voltage and minimum starting conditions (voltage and/or short circuit MVA) and any other specified conditions.

f) Expected efficiency as determined in accordance with IEEE 115 or IEC 60034-1, or by certified data from previously tested designs. The purchaser in consultation with the vendor shall specify the method to be used. For motors with pulsating current, efficiency under actual operating conditions will be used to evaluate the life-cycle cost.

NOTE To verify performance, it may be necessary to check motor current pulsations under load in the field using an appropriate digital waveform recording instrument.

• g) When specified, the guaranteed efficiencies (with no negative tolerance) at $^1/_4$, $^1/_2$, $^3/_4$, and full load calculated in accordance with the agreed upon test method from 6.2.2.1 f.

• h) When specified, for motors that drive reciprocating compressors or pumps requiring a variable torque during each motor revolution, the maximum current variation under actual operating conditions, the calculated efficiency under these conditions based on an expected minimum efficiency, and the method of calculating the efficiency under operating conditions. The effect of voltage drop in the power supply system shall be considered. The purchaser will furnish the value for the minimum short-circuit kilovolt-amperes of the power supply system. Compressor crank-effort diagrams and other relevant data will be supplied by the purchaser for the determination of current pulsations.

i) A description of the field application and synchronization circuit and devices.

j) Synchronizing power per electrical radian (Pr) at no load and full load.

6.2.2.2 *For generators*.

a) Short circuit currents vs. time for three phase, line to line and line to ground fault conditions.

b) Transient (momentary) voltage regulation during sudden application and removal of 100 % full load or any other specified load value.

c) Total and single harmonic voltages expressed in % of fundamental voltage for line to line and line to neutral with unit operating at rated voltage, frequency and no load.

d) The inertia of the rotor.

e) Zero sequence reactance to enable the purchaser to complete ground fault calculation.

f) Expected efficiency as determined in accordance with IEEE 115 or IEC 60034-1-1, or by certified data from previously tested designs. The purchaser in consultation with the vendor shall specify the method to be used.

• g) When specified, the guaranteed efficiencies (with no negative tolerance) at $^1/_4$, $^1/_2$, $^3/_4$, and full load calculated in accordance with the agreed upon test method from 6.2.2.2 f.

h) Synchronizing power per electrical radian (Pr) at no load and full load.

• **6.2.2.3** When specified, information shall be supplied with the proposal to facilitate a preliminary power system short-circuit analysis. The required machine parameters include "X_{dv}" [rated voltage (saturated) subtransient reactance], X_{2v} [rated voltage (saturated) negative-sequence reactance], T_{a3} [rated voltage (saturated) armature time constant (seconds)], rated MVA, and rated terminal voltage.

NOTE IEEE Std C37.010, Table 8, footnote "a," describes the use of the above information to determine the effective resistance to be used for the *X/R* of the machine during short circuit calculations.

6.2.3 The vendor shall provide utility requirements such as power for auxiliary devices (e.g. heaters), air, cooling water and lube oil, including the quantity of water or lube oil required at the supply pressure and the heat load to be removed by the water or oil. Approximate data shall be defined and clearly identified as such. This information shall be entered on the data sheets.

6.2.4 The vendor shall provide net weights and maximum erection weights with identification of the item. These data shall be stated individually where separate shipments, packages, or assemblies are involved. These data shall be entered on the data sheets.

6.2.5 The vendor shall provide a preliminary dimensional outline drawing showing the location of inlet and discharge connections and the direction of rotation when viewed from the end opposite the drive end.

6.2.6 If applicable, the vendor shall provide schematic diagrams of auxiliary sub-systems such as lube-oil or cooling water systems.

6.2.7 The vendor shall provide typical drawings and literature to fully describe the details of the offering or offerings. The vendor shall show shaft sealing and bearing details, internal construction, rotor construction, and the method of attaching the amortisseur bar to the shorting ring if applicable.

6.2.8 The vendor shall provide a specific statement that the complete machine and all auxiliary equipment are in strict accordance with this standard. If the machine and auxiliary equipment are not in strict accordance, the vendor shall include a specific list that details and explains each deviation. Deviations may include alternative designs or systems equivalent to and rated for the specified duties.

6.2.9 The vendor shall provide an explicit statement of the proposed guarantee and warranty (see Section 5).

6.2.10 The vendor shall provide a statement of the fixed number of weeks required to effect shipment after receipt of the order and all engineering data. Separate times shall be stated for multiple shipments, as in the case of separate packages or assemblies or multiple units.

6.2.11 The vendor shall provide a statement of the time(s) after placement of the order for transmittal of the contract data and drawings (see 6.4.1 and Annex C). This information shall be presented in the form of an explicit schedule.

6.2.12 The vendor shall provide an itemized list of the special tools included in the offering. The vendor shall list any metric items included in the offering.

• **6.2.13** The vendor shall provide a separate price for each optional test that is specified and a packaged price for all the tests specified on the data sheets.

• **6.2.14** When specified, the vendor shall provide an outline of all necessary special weather and winterizing protection required for the machine and its auxiliaries for start-up, operation, and idleness. The vendor shall quote separately the protective items he/she proposes to furnish.

6.2.15 The vendor shall provide technical data, specifications, similar information or catalog cut sheets that describe all the auxiliary equipment.

• **6.2.16** When specified, the vendor shall provide a statement of the rate for furnishing a competent erection supervisor, as well as an estimate of the length of time the supervisor's services will be required under normal conditions.

• **6.2.17** When specified, materials shall be identified in the proposal with their applicable AISI, ANSI, ASTM, and ASME or ISO numbers, 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.

6.3 The vendor shall support a coordination meeting to be held as soon as possible after the purchase order placement. The meeting should include the end user, the electric machine supplier, driven equipment/prime mover supplier, ASD supplier (as applicable), engineering firm, consultant and other sub suppliers as applicable. The following items should be reviewed:

a) the purchase order, scope of supply, unit responsibility, sub-vendor items, document procedures and lines of communications;

b) contract data and API 546 data sheets (see 6.4);

c) API 546 comments and exceptions, applicable specifications, and previously agreed exceptions;

d) speed torque curves and rotating equipment inertias;

e) schedules for the transmittal of data, production, testing and shipment (Annex C);

f) the quality assurance program and procedures;

g) equipment performance, alternate operating conditions, startup, shutdown and any operating limitations;

h) instrumentation; controls and any other interfaces;

i) scope, performance, operating parameters, P&IDs, etc. for auxiliary sub-systems such as lube oil or cooling water consoles;

j) identification of items requiring design review;

k) inspection, test procedures and related acceptance criteria; and

l) other technical items.

6.4 Contract Data

Subsequent to the issuance of a contract, the vendor shall revise and re-submit the previously supplied proposal data (see 6.2) and completed "Vendors Sections" of the motor or generator data sheets in Annex A or Annex B. These data sheets shall be marked "Applicable for Purchase" on Line 5 of Sheet 1.

6.4.1 The vendor shall complete the Vendor Drawing and Data Requirements form (see Annex C), detailing 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.

6.4.2 The drawings and data shall be identified on transmittal letters and in title blocks or pages with the following information:

a) the purchaser/user's corporate name;

b) the job/project number;

c) the equipment name and item number;

d) the purchase order number;

• e) any other identification specified in the purchase order; and

f) the vendor's identifying shop order number, serial number, or other references required to completely identify returned correspondence.

6.4.3 If not previously supplied with the proposal, the vendor shall supply a recommended list of spare parts complete with catalog numbers and ordering information.

• **6.5** When specified, a design review meeting shall be held at the electric machine vendor's manufacturing facility at the time certified drawings and data are available for approval by the purchaser. The meeting should include the end user, electric machine supplier, driven equipment/prime mover supplier, ASD supplier (as applicable), engineering firm, consultant and other sub suppliers as applicable. Suggested items for review are as follows:

a) contract data and API 546 data sheets (see 6.4);

b) performance curves including; thermal damage curves, acceleration times, allowable stall times and temperatures of rotor parts;

c) method of efficiency determination and guarantee of efficiency;

d) current pulsations for reciprocating loads;

e) number of starts allowed;

f) inertia of the machine and coupled equipment;

g) stator winding and winding insulation system;

h) rotor winding, mechanical design, fits, construction, balance;

i) shaft design stress, short-circuit torques;

j) torsional and lateral critical speed analysis, and rotor sensitivity analysis (response to an intentional unbalance);

k) foundation and base stiffness;

l) coupling type and coordination;

m) bearing and seal details;

n) bearing and coupling insulation;

o) lubricating oil type and oil inlet temperature range;

p) test agenda;

q) “Witness" and “observe" points for inspections and tests;

r) data for performance of electrical power system studies by the purchaser;

s) excitation system design and interconnection with other equipment;

t) review of machine drawings, and where applicable: P and IDs, auxiliary sub-system console drawings;

u) installation and commissioning procedures; and

v) packaging, shipping and long term storage.

NOTE It is important that the design review meeting be held early enough in the project cycle so any needed design modification will not adversely affect machine cost and manufacturing schedule.

6.6 Drawings

• **6.6.1** Documents and drawings shall be supplied in a mutually agreed electronic format. In addition, the purchaser will state in the inquiry and in the order the number of prints and/or reproducibles required and the times within which they are to be submitted by the vendor (see 6.4.1 and Annex C) When specified by purchaser, vendor’s performance curves, response curves, etc. shall be supplied in a mutually agreed electronic tabular format so that purchaser can insert the information into computer program models.

• **6.6.2** The purchaser will promptly review the vendor’s drawings when he/she receives them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the drawings have been reviewed, the vendor shall furnish certified copies in the quantity specified. Drawings shall be clearly legible.

6.6.3 The drawings furnished shall contain sufficient information so that when they are combined with the manuals specified in 6.8, the purchaser may properly install, operate, and maintain the ordered equipment. As a minimum, the following details shall be provided.

a) Overall dimensions and weights for each separately installed piece. Maintenance clearances and weight-handling capability required for erection and maintenance shall be included.

b) The direction of rotation.

c) As applicable, the size, type, location, and identification of all the purchaser’s connections, including power, control, and instrument wiring; supply and drain details for lubrication oil and cooling water, and inlet and discharge details for cooling or purge air, as well as frame vents and drains. Connections plugged by the vendor shall be identified.

d) Where applicable, the make, size, and type of couplings.

e) Detail drawings of the bearings and bearing seals. The drawings shall include the manufacturer’s type and catalog number of the bearings and seals.

f) A list of any special weather-protection and climatization features supplied by the vendor and required by the purchaser.

g) A list of auxiliary or other equipment furnished by the vendor for mounting by the purchaser.

h) Rigging provisions for removal of parts that weigh more than 135 kilograms (300 lb).

i) Complete information to permit adequate foundation design by the purchaser. This shall include the following items:

1) the size and location of foundation bolts;

2) the weight distribution for each bolt/sub-soleplate location;

3) any unbalanced forces or moments generated by the unit or units in the specified operating range;

4) the location of the center of gravity; and

5) foundation forces as a result of worst case transient conditions.

6.6.4 The vendor shall supply schematic diagrams and bills of materials for each auxiliary system in the vendor's scope of supply, including control systems, as well as dimensional outline drawings for accessories and instruments. The bills of materials shall include and identify all components by make, type, size, capacity rating, materials, and other data as applicable.

6.6.5 Each drawing and diagram shall have a title block in the lower right corner, showing certification, reference to all identification data specified in 6.4.2, the revision number and date, and the drawing title. The title block shall be visible when the drawing is folded to A4 metric size or 8 $^1/_2$ in. × 11 in. Bills of materials shall be similarly identified.

6.6.6 A complete list of vendor drawings shall be included with the first-issue major drawings. This list shall contain the titles and a schedule for transmission of all the drawings to be furnished by the vendor.

6.7 Final Data

6.7.1 Subsequent to completion of manufacture and testing, the vendor shall revise and re-submit the previously supplied purchase data (see 6.4) and completed "Vendors Sections" of the motor or generator data sheets in Annex A or Annex B. These data sheets shall be marked "Applicable for As Built" on Line 5 of Sheet 1. Drawings shall be marked and re-submitted as "Final."

6.7.2 The vendor shall make the following additional information available to the purchaser.

• a) A record of shop test data (which the vendor shall maintain for at least 5 years after the date of shipment). Included are the shop test reports for auxiliary sub-systems such as lube oil or cooling water consoles. When specified, the vendor shall submit certified copies of the test data to the purchaser before shipment. This requirement is also applicable to sub-vendors and sub-contractors.

• b) When specified, the calculated rotor-response curves.

c) The rotor-balance report.

d) The vendor shall supply complete winding data with the Instruction Manuals. The data shall be sufficient to permit the owner to have a set of stator coils built if required. The data shall include:

1) number of coils, winding connection and throw;

2) total copper weight, copper strand sizes and details of both turn and ground wall insulation;

3) turns per coil and number of parallels;

4) length of iron including vents;

5) stator bore diameter, slot depth and width, plus depth below wedge; and

6) finished coil dimensions in slot, plus details of semi-conducting finish and stress or gradient paint treatment at the coil end turns, if any.

6.8 Instruction Manuals

• **6.8.1** The number of manuals, the specific information, and the detail required for each purchase will be defined in the purchasing document included with the inquiry.

6.8.2 The vendor shall provide written instructions and a cross-referenced list of all drawings to enable the purchaser to install, operate, and maintain the complete equipment ordered. This information shall be compiled in manuals with title pages containing section titles and complete lists of the included reference drawings by title and drawing number. If the instruction manuals apply to more than one model or series of equipment, the instructions shall clearly indicate the specific sections that apply to the equipment involved.

6.8.3 The installation manual shall include any special information required for proper installation design and actual installation that is not on the drawings (which shall be compiled in a separate manual). This manual shall be forwarded at a time mutually agreed upon in the order but not later than the final-issue prints. It shall contain information such as special alignment procedures, bearing and bearing seal installation considerations, utility specifications (including quantity), and all installation design data.

6.8.4 Operation and maintenance manuals shall be forwarded no more than 2 weeks after successful completion of all specified tests. If required, these manuals shall include a section of special instruction for operation at specified extreme environmental (such as temperature) conditions. The following items shall be included in the manual.

a) Instructions covering start-up, normal shutdown, emergency shutdown, operating limits, and routine operational procedures.

b) Outline and sectional drawing, schematics, and illustrative sketches in sufficient detail to identify all parts and to clearly show the operation of all equipment and components and the method of inspection and repair. Standardized sectional drawings are acceptable only if they represent the actual construction.

• c) When specified, detailed instructions, including pictures and sketches, outlining the appropriate methods for disassembly, inspection, re-assembly and maintenance of the machine's bearings and bearing seals.

• **6.8.5** When specified, one complete set of photographs showing the assembly of the machine shall be provided. Each step of the bearing assembly shall be individually photographed.

• **6.8.6** When specified, copies of documentation for Nationally Recognized Testing Laboratory (NRTL) certification, positive material identification (PMI), material certification, or other unique records relating to the provision of the order.

Annex A

Synchronous Motor Data Sheets

This annex comprises data sheets for motors purchased to API 546, third edition. There are two sets of sheets, one for US Standard Units, and one for Metric Units.

SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 1 OF 11

		Rev
1	FOR / USER ____ DRIVEN EQUIPMENT ____	
2	SITE / LOCATION ____ QUANTITY ____	
3	SUPPLIER ____ ▽ SUPPLIER PROJECT NO. ____	
4	ITEM NAME ____	
5	Applicable To: ❍ Proposal ❍ Purchase ❍ As Built	
6	**GENERAL**	
7	NOTE: **(Alpha key code)** ❍ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**	
8	**Bold Type Indicates Typical Selection**	
9	**Basic Data:**	
10	Applicable Standards (1.3.1; 1.3.2; 1.6): ❍ **North American (i.e., ANSI, NEMA)** ❍ International (i.e., IEC, ISO)	
11	Nameplate Power (2.2.1.1): ____ HP ____ **Service Factor (2.2.1.3)** ____ RPM (Synchronous)	
12	____ Volts (2.2.1.2) ____ Phase ____ Hertz Duty: ❍ Continuous ❍ Other ____	
13	Rated PF: ____ Insulation Class: ____ Voltage and Frequency Variations (2.2.1.2.1) ____	
14	Motor Power Source: ❍ Sine Wave Power ❍ ASD Power ❍ LCI Power	
15	Stator Temperature Rise (2.3.1.1) ____ °C Above ____ °C By RTD	
16	Rotor Temperature Rise ____ °C Above ____ °C By Resistance ❍ Sealed Exciter Windings Required (2.3.1.6)	
17	☐ Manufacturer's Type ____ ☐ Frame Size ____	
18	Other: ____	
19	**Site Data (2.1.2):**	
20	Area Classification (2.1.8): ❍ Nonclassified ❍ Classified as: Class ____ Group ____ Division ____ Autoignition Temp ____ °C	
21	Class ____ Group ____ Zone ____	
22	Maximum Sound Pressure Level (2.1.3): ❍ **85 dBA @ 3 ft. NO-LOAD, FULL VOLTAGE/FREQUENCY, SINE WAVE POWER** ❍ ____ dBA	
23	Ambient Temperature: Max ____ °F Min ____ °F	
24	Relative Humidity: Max ____ % Min ____ %	
25	Motor Location: ❍ Indoor ❍ Outdoor Roof Over Motor: ❍ Yes ❍ No	
26	Building Temperature Controlled: ❍ Yes ❍ No Site Elevation: ____ ft.	
27	Nonmassive Foundation (2.4.6.1.2), Description ____	
28	**Unusual Conditions:**	
29	Dust (2.4.1.2.2,c) ____ Chemicals (2.1.2) ____	
30	Seismic Loading (2.4.2.2) ____ Corrosive Agents (2.4.10.1.2) ____	
31	Other: ____	
32	**Enclosure (2.4.1.2.1)**	
33	❍ Weather Protected (WP) (2.4.1.2.2) ❍ Type 1 ❍ Type II	
34	Air Filters: ❍ Provision Only (3.5.2) ❍ Required (3.5.4) ❍ **90%, 10 µm** ❍ Other ____	
35	▷ Manufacturer ____ ▷ Type ____ ▷ Model ____	
36	Differential Pressure Switch (3.5.5): ❍ Provision Only ❍ Required ❍ Differential Pressure Guage (3.5.5)	
37	▷ Manufacturer ____ ▷ Type ____ ▷ Model ____	
38	❍ Explosion Proof ❍ TEFC (2.4.1.2.3) ❍ Drip Proof Guarded ❍ TEPV (2.4.1.2.3) ❍ Other ____	
39	❍ TEAAC (2.4.1.2.3) Tube Materials (2.4.10.8,a): ❍ Copper ❍ Copper Alloy	
40	❍ Aluminum Alloy ❍ Stainless Steel ❍ Other ____	
41	Notes: ____	
42	____	
43	____	
44	____	
45	____	

API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 2 OF 11

GENERAL (CONTINUED) Rev

NOTE: (Alpha key code) — TO BE COMPLETED BY PURCHASER (m or l) — BY MANUFACTURER WITH PROPOSAL (o or n) — BY MANUFACTURER AFTER ORDER (s or q) — BY MANUFACTURER OR PURCHASER (w or u)

Bold Type Indicates Typical Selection

TEWAC (2.4.1.2.4) Tube Materials (2.4.10.8, b): **Cu-Ni** Other ______

Redundant Coolers (2.4.1.2.4, b): Yes No Exchanger Location/Orientation (2.4.1.2.4, c) ______

Cooling Water Conditions per 2.4.1.2.4, a: Yes No (Other) ______

Water Flow (GPM) Max ______ Min ______ Water Pressure (PSI) Max ______ Min ______

Tube Construction (2.4.1.2.4, d; 2.4.10.8, c): **Single Tube** Double Tube

Flow Sensor Local Indicator Required (2.4.1.2.4, g) Relay Contacts: NO NC

Air Temperature Sensor Required (2.4.1.2.4, h), Type ______

Leak Detection Required **Inner** Outer Type and Description ______

High Flow Alarm Set Point ______ GPM Low Flow Shutdown Set Point ______ GPM

Provision for Pre-Start Purging (2.4.1.1, e) ______ Marine Grade Stainless Steel Fasteners (2.4.1.1, c)

Degree of Protection IP (2.4.1.2.1) IP ______ Method of Cooling IC (2.4.1.2.1) IC ______

Other: ______

Mounting:

Horizontal: Foot Mounted Flange Mounted Flange Details ______

Vertical: Shaft Up Shaft Down P-base Flange Diameter ______

Pedestal Axial Stator Shift Required (2.4.2.15)

Engine Type Bearings Furnished By ______ Shaft Furnished By ______

Baseplate: Furnished By (2.4.2.6): ______ Soleplate: Furnished By (2.4.2.6): ______

Special Connections for Field Piping (2.4.3.1): ______

When Rotor Dynamic Analysis Is Specified, List of Foundation Data Required From Purchaser (2.4.6.1.2): ______

______

______

Electrical System:

Primary Power Source ______ Volts ______ Phase ______ Hertz Maximum Ground Fault ______ Amps

Method of System Grounding (3.6.2.3) Resistance Reactance Ungrounded Solid

Fault Current at Machine Terminals (3.1.2) ______ MVA Let-Through Energy (3.1.2): ______ I^2t (Ampere-squared seconds)

Min S.C. at Motor Bus (2.2.4.2, c) ______ MVA at ______ kV_{base} X/R Ratio: ______

Other: ______

Motor Starting (2.2.4): **ACROSS-THE-LINE STARTING AT 80% OF RATED VOLTAGE (2.2.4.1)**

Loaded Unloaded Partially Loaded ______ % Starting Torques in Excess of IEC or NEMA (2.2.3.1) ______ %

Load Reacceleration Required (2.2.3.2, b): No Yes Reacceleration Curve No. ______

If Yes, Complete the Following: Max Voltage Interruption ______ Sec. Voltage at Motor Terminals ______ Volts

Other Starting Method (2.2.4.2, a) Type ______ Reduced Voltage ______ Volts

Starting Capability Data (2.2.4.2, b): Min. ______ Volts at Machine Terminals Under ______ Amps Inrush Current

or (2.2.4.2, c): Min. S.C. kVA ______ and ______ X/R ratio and ______ Volts at Machine Terminals

Number of Full Voltage Starts if Not 5000 (2.2.5.1; 2.4.5.1.1): ______ Consecutive Starts Different From Table 4 (2.2.5.2): ______

Notes: ______

______

______

______

______

______

SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 3 OF 11

GENERAL (CONTINUED)

NOTE: (Alpha key code) ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)** Rev

Bold Type Indicates Typical Selection

Adjustable Speed Drive Conditions (2.1.5):

○ ASD ○ ASD with DOL Start ○ Bypass @ Utility Frequency

○ Variable Torque Speed Range: Min Speed ____ RPM ____ ft-lb Max. Speed ____ RPM ____ ft-lb

○ Constant Torque Speed Range: Min Speed ____ RPM Max. Speed ____ RPM ____ ft-lb

○ Constant Power Speed Range: Max Speed ____ RPM ____ ft-lb

Other: ____

Bearings:

Bearing Type: ○ **Hydrodynamic (2.4.7.1.1)** ○ Split Sleeve (2.4.7.1.2) ○ Tilting Pad (2.4.7.1.2) ○ Oil Ring Required (2.4.8.1)

○ Antifriction (2.4.7.1.3)

○ Thrust Bearing (2.4.7.1.5) Max Driver Thrust Downthrust Momentary ____ lbs Upthrust Momentary ____ lbs

Continuous ____ lbs Continuous ____ lbs

○ Bearing Constant-Level Sight Feed Oilers Required (2.4.7.2.2) Type: ____

○ Special Seals for Gas Purge (2.4.7.3.a) ○ Non-conducting Seals (2.4.7.3, b)

Other: ____

____

LUBRICATION SYSTEM

▷ **SELF-LUBE (2.4.8.1)** ▷ Pressurized Lube Required (2.4.8.1) System Supplied By (2.4.8.4): ____ ○ Common With Driven Equipment

○ Per API 614: ____ -purpose oil system (2.4.8.6) ○ Main Oil Pump Required: ○ Integral Shaft Driven ○ Separate

○ Oil Rings Not Provided

▷ Type/Viscosity of Oil (2.4.8.8) ____ ▷ Pressure (2.4.8.4; 2.4.8.5) ____ PSIG

▽ Total Bearing Oil Requirements (6.2.3): ▽ ____ GPM ▽ ____ PSI ▽ Heat Loss To Be Removed ____ kW

Antifriction Bearings: ▷ Grease: Type ____ Oil Mist (2.4.7.4.1) ○ Pure mist ○ Purge mist

Other: ____

SPECIAL CONDITIONS:

○ Shaft and Spider one piece forging for 4 or more poles (2.4.5.1.2, b; 2.4.5.1.4)

○ Special Vibration Requirements (4.3.3.10) ____

○ Efficiency Evaluation Factor (EF) (6.2.1) ____ (value) ____ (currency) /kW applied at ____ % of F.L.

○ National, State / Provincial, or Local Codes (2.1.8): ____

○ External Forces on Motor Housing That May Affect Site Performance (2.1.13; 2.4.4): ____

○ Special Overspeed Requirement (2.4.5.2.7): ____

Other: ____

MAIN CONDUIT BOX

Main Terminal Box (3.1.1):

○ Box Location ____ Conductor Size ____ Type ____ Insulation ____ Qty. Per Phase ____

○ Quick Disconnect Type Bushing Studs or Receptacles (3.1.6, f) ____

○ Space for Termination of Shielded Cables (3.1.6, e) Cable Entering From (3.1.4): ○ Top ○ Bottom ○ Drive Side ○ Non-Drive End Side

○ Both Ends of Stator Winding Brought Out To Terminal Box (2.2.2.2) ○ Thermal Insulation (3.1.6, a)

Cable Between Stator Windings and Main Terminals (2.3.1.11): ○ Yes ○ No Description: ____

○ Space Heaters (3.1.6, b): ○ Temp. Code ____ ____ Volts ____ Phase ____ Hz □ ____ kW

○ Differential Protection Current Transformers (2.2.2.2; 3.1.6, h; 3.1.8; 3.6.3): Accuracy Class ____ Ratio ____ Quantity ____

Type: ○ Self-balancing ○ Full Differential ▷ Supplied By ____ ▷ Mounted By ____

Notes: ____

SYNCHRONOUS MOTOR
API 546 3RD Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS

JOB NO. ______ ITEM / TAG NO. ______
PURCHASE ORDER NO. ______
REQ. / SPEC. NO. ______
REVISION NO. ______ DATE ______ BY ______
PAGE 4 OF 11

1 **MAIN CONDUIT BOX (CONTINUED)** Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 ○ Surge Capacitors (3.1.6, g; 3.6.2.1): ○ Microfarads ____ ▷ Supplied By ____ ▷ Mounted By ____

5 ○ Surge Arresters (3.1.6, g; 3.6.2.2): ○ kV Rated ____ ▷ Supplied By ____ ▷ Mounted By ____

6 ○ Current Transformers (3.1.6, h) for Ammeter ○ Accuracy Class ____ ○ Ratio ____ ○ Quantity ____

7 ▷ Supplied By ____ ▷ Mounted By ____

8 ○ Potential Transformers (3.1.6, j) for Voltmeter ○ Accuracy Class ____ ○ Ratio ____ ○ Quantity ____

9 ○ Fuses Required ▷ Supplied By ____ ▷ Mounted By ____

10 ○ Provision for Purging (3.1.6, c)

11 ○ Removable Links (3.1.6, d) ○ Silver- or Tin- Plated Bus Joints (3.1.6, i) ○ Ground Bus (3.1.6, k)

12 ○ Insulated Terminations and Interior Jumpers (3.1.6, m) Other: ____

13 **ACCESSORIES**

14 ○ **Frame Space Heaters (3.4):** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase □ ____ kW

15 ○ **Bearing Heaters (2.4.8.3):** Temp. Code ____ Type ____ ____ Volts ____ Phase □ ____ kW

16 ○ **Exciter Space Heaters:** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase □ ____ kW

17 **Winding Temperature Detectors (3.2.1):** ○ **Three Per Phase, 3 Wire Platinum, 100 Ohms at 32°F** ○ Ground One Common Lead (3.2.1.2)

18 ○ Other Detector: Qty / Phase ____ Type ____ Material ____ Wires ____

19 ○ Thermocouples: Qty / Phase ____ Type ____

20 ▽ Recommended Settings: Alarm ____ °F Shutdown ____ °F

21 **Monitors and Devices** ○ Monitor for Shaft Grounding Brush Replacement (2.4.7.1.9)

22 ○ Test Device For Rotating Electronic Components (2.5.3.8) ○ Rotating Diode Failure Detection (2.5.3.12)

23 ○ Online Rotor Monitoring System (2.5.3.10): Description: ____

24 **Exciter Power Supply** ○ Permanent Magnet Generator (2.5.3.13) ○ Constant Voltage Transformer (2.5.1.5) ○ Phase Controlled Rectifier (2.5.1.5)

25 ○ Other (2.5.1.5) ____

26 **Auxiliary Equipment Enclosures (3.1.4):** ○ Box Location (Facing Opposite Drive End) ____

27 Conduit/Cable Entry From: ○ Bottom ○ Other: ____

28 **Hydrodynamic & Thrust Bearing Temperature Devices (3.3):**

29 ○ Provision Only ○ Install per API 670 (3.3.1) ○ Other ____

30 ○ **RTD's (3.3.1)** Qty / Brg. ____ Type ____ Material ____ Wires ____ ○ Ground One Common Lead (3.2.1.2)

31 ○ Thermocouple: Qty / Brg. ____ Type ____ Material ____ Wires ____

32 ○ Dial Type Thermometers (2.4.7.1.16): Type ____ ○ Alarm Contacts Number of Contacts ____ ○ NO ○ NC

33 Location of Bearing Temperature Sensor Wire Terminations: ▷ Terminal box at motor side ▷ In the Stator RTD T Box ▷ Conduit Head at Bearing

34 ▽ Bearing Temperature Recommended Settings: Alarm ____ °F Shutdown ____ °F

35 ▽ Thrust Bearing Temp. Recommended Settings: Alarm ____ °F Shutdown ____ °F

36 **Vibration Detectors (3.8):** **Motors 1200 rpm and higher** Installed Qty / Bearing: ○ **TWO (3.8.1)** ○ Four (3.8.2)

37 Phase Reference Probe (3.8.1): ○ Provisions Only ○ **INSTALLED**

38 **Motors less than 1200 rpm** Installed Qty / Bearing: ○ Two (3.8.1) ○ Four (3.8.2)

39 Phase Reference Probe (3.8.1): ○ Provisions Only ○ Installed

40 Vibration Probe Leads Protected by (3.8.1.1; 3.9.1; 3.9.2): ○ Liquidtight Flexible Metal Conduit, Length ____ ft.

41 ○ Other Description: ____

42 ▷ Probe, Oscillator-Demodulator Mfr. ____ Model / Series ____

43 ▷ Probe Supplied By ____ Installed by ____ ▷ Osc.-Demod. Furnished By ____ Installed by ____

44 Bearing Housing Seismic Sensors (3.8.3) ○ Provisions Only ○ Installed Sensor Type ____ Sensor Mfr. ____

45 Qty / D.E. Bearing ____ Location (H, V, A) ____ Qty / N.D.E. Bearing ____ Location (H, V, A) ____

	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 5 OF 11

ACCESSORIES CONTINUED

Rev

NOTE: (Alpha key code) — ○ TO BE COMPLETED BY PURCHASER (m or l) — □ BY MANUFACTURER WITH PROPOSAL (o or n) — ▽ BY MANUFACTURER AFTER ORDER (s or q) — ▷ BY MANUFACTURER OR PURCHASER (w or u)

Bold Type Indicates Typical Selection

▷ Sensor Supplied By ____ Installed by ____ ▷ Transducer Furnished By ____ Installed by ____

Location of Vibration Sensor Wire Terminations: ▷ Terminal box at motor side ▷ Within Sensor Housing ▷ Other ____

Vibration Switch: ○ Manual Reset ○ Electric Reset Switch Type: ____ Model: ____

Terminal Head or Box (3.1.11) ____

Alarm and Control Switches (3.6.1): SPDT 10 Amp 115 Volt ○ DC Rated Contacts: ____ ○ **AC Rated Contacts:** ____

Partial Discharge Detectors (3.6.4; 3.1.6, l) ○ Yes Describe Required System: ____

____

Separately Powered Auxiliary Fan(s) (2.4.10.6.3): Driver Information (where applicable) ▷ Standard No. ____

Quantity ____ Location ____ Encl. ____ HP ____ RPM ____ ____ Volts ____ Phase ____ Hertz

Quantity ____ Location ____ Encl. ____ HP ____ RPM ____ ____ Volts ____ Phase ____ Hertz

Other: ____

____

CONTROLS

Motor Vendor to Furnish

○ Manufacturer's Standard Excitation Control (Including Application & Protection) Package for Mounting in:

○ Purchaser's Switchgear ○ Vendor Furnished Control Panel

○ Separate Control Devices, as Checked, for Mounting in:

○ Purchaser's Switchgear ○ Vendor Furnished Control Panel

○ Completely Assembled Control Panel with Devices as Checked (3.6.5.2)

Devices Mounted on Front of Panel, Labeled as Indicated

○ Motor "Start-Stop" Switch ○ Pilot Lights: ○ "RUN" ○ "STOP" ○ "READY"

○ Ammeter (0 - 5 A), 0 - ____ A Scale, "MOTOR AMPERES"

○ Voltmeter (0 - 150 VAC), 0 - ____ kV Scale, "MOTOR VOLTAGE"

○ "POWER FACTOR" Meter, 0.80 - 1 - 0.80 Scale or ____ - ____ - ____ Scale

○ Ammeter, 0 - ____ Amps Scale, "EXCITER FIELD AMPERES"

○ Rheostat, 0 - ____ VAC, Scale ____ A, "EXCITER FIELD"

○ Potentiometer, "EXCITER FIELD" ○ "EXCITER FIELD ON-OFF" Test Switch

○ Timer, 0 Sec - ____ Sec, On Delay, "INCOMPLETE SEQUENCE"

○ Timer, 0 Sec - ____ Sec, On Delay, "OUT-OF-STEP"

○ Overcurrent Relays (3), Instantaneous, 0.5 - 2 A Range, "DIFFERENTIAL PROTECTION": Type: ____

○ Other ____

○ Overtemperature Relay, 122 - 374^{o}F Range, For Use with ____ Ohm RTD, "STATOR TEMPERATURE"

Quantity ____ Type ____

○ Alarm Panel ○ Automatic Power-Factor Controller (2.5.1.3) ○ VAR Controller (2.5.1.3)

○ Vibration Probe Monitors: Manufacturer ____ Model ____

○ Temperature Indicator, ____ ^{o}F

○ Other ____

Devices Mounted Inside Panel, Labeled to Coincide with Drawing Identification:

○ Control Power Transformer, Constant Voltage, ____ kVA, ____ V - 120 V Rated to Maintain 95 % Secondary Voltage with 50% Sag of Primary Voltage (2.5.1.5) ○ Phase Controlled Rectifier (2.5.1.5)

○ Other (2.5.1.5) ____

Notes: ____

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 6 OF 11

1 **CONTROLS CONTINUED** — Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 ○ Full-Wave Bridge, Silicon Rectifiers ______ A (Min of 125 % of Exciter Field Amperes), Convection Cooled

5 ○ Contactor Exciter Field Current

6 ○ Field Monitor Relay, to Switch and Signal on Loss of Field or Out of Step Condition

7 ○ Auxiliary and Timing Relays, as Required ○ Surge Suppressors and Fuses, as Required

8 ○ Terminal Blocks, Heavy Duty, Identified by Unique Numbers, Number as required with 20 % Spares ______

9 ○ Switches required for Alarm and Control devices (3.6.1): Contacts: **AC** ______ DC ______

10 ○ Control Panel Wiring Entrance: ○ Top ○ Bottom ○ Side

11 ○ Other: ______

12 **DRIVEN EQUIPMENT INFORMATION**

13 Driven Equipment: Tag No. ______ Description ______ Location ______

14 Type of Load: Centrifugal: ○ Compressor ○ Pump ○ Fan ○ Other ______

15 Positive Displacement: ○ Reciprocating Compressor: Compressor Factor "C" ______

16 Maximum Current Pulsation (NEMA Defined) (2.2.6.1, c): ○ 40% ○ 66% ○ Other: ______

17 ○ Calculated Efficiency Based on Current-Pulsation Operating Conditions (6.2.2.1, h) ______

18 Driven Equipment Mfr. ______ Type / Model No. ______ RPM ______

19 Load Speed-Torque Curve No. (2.2.3.2 a) ______ Crank-Effort Chart or Torque-Effort Curve No. (6.2.2.1, h) ______

20 Total Driven-Equipment WK^2 (2.2.3.2, c) ______ lb-ft^2 at ______ RPM

21 Driver Connection to Load: ○ Direct Coupled ○ V-Belt Connection ○ Through Gearbox

22 Speed-Increasing-Reducing Gear (2.2.3.2, c): Ratio ______ Gear WK^2 (2.2.3.2,c) ______ lb-ft^2 at ______ rpm

23 Motor Shaft Extension (2.4.5.1.9): ○ Cylindrical Fit ○ Taper Fit ○ Flange

24 Rotation ***Viewed from Non Drive End of Motor:*** ▷ Clockwise ▷ Counterclockwise ▷ Bi-directional

25 Coupling (2.4.9.4): Type ______

26 ○ Manufacturer's Standard ○ Per API 671 Mfr. ______ Type / Model ______

27 Coupling WK^2 (2.2.3.2, c) ______ lb-ft^2 at ______ rpm Mass Moment of Coupling Half (2.4.6.2.2, f) ______ lb-ft^2

28 Supplied By: ○ Motor Mfr ○ Driven Equipment Mfr ○ Purchaser ○ Others ______

29 Mounted By: ○ Motor Mfr ○ Driven Equipment Mfr ○ Purchaser ○ Others ______

30 Other: ______

31 **MISCELLANEOUS**

32 ○ Manufacturer's Standard Paint ○ Extra Coat at Shipment ○ User's Special Paint ______ ○ Outline for Special Weather Protection (6.2.14)

33 ○ Proof of Nonsparking, Corrosion-Resistant Fan (2.4.10.6.1) ○ Quantity of Special Tools and Lifting Required (2.1.12; 2.4.2.13): ______

34 ▷ Special Low-Temp Material Requirements (2.4.10.4) ______

35 ▷ Special Winterizing Requirements (6.2.14) ______

36 ○ Materials To Be Identified With ANSI, ASTM, or ASME Numbers (6.2.17) ______

37 ○ Typical Drawings & Literature with Proposal ○ Electronic Instruction Manuals (6.6.1) Qty: ___ ○ Photos showing assembly steps required (6.8.5)

38 ○ Performance Curves Supplied in Digital Format (6.6.1) Digital Format Description: ______

39 ○ Manufacturer To Supply Curve Data in Tabular Format (6.6.1) ○ NRTL Certification (6.8.6) Qty: ___ ○ PMI Certification (6.8.6) Qty: ___

40 ○ Detailed instructions and photographs for disassembly and inspection (6.8.4, c) Qty: ___ ○ Certified Drawings (6.6.2) Qty: ___

41 ○ Type Tests and Design Information Verifying All Gasket Materials are Impervious to Lube Oil and Chemicals (3.1.4), Qty of Type Tests Documentation ___

42 ○ Special Identification for Transmittals (6.4.2, e) ○ Separate Nameplate with Purchaser's Information (2.4.11.4)

43 ______ ______

44 ______ ______

45 Notes: ______

SYNCHRONOUS MOTOR
API 546 3RD Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS

JOB NO. ____ ITEM / TAG NO. ____
PURCHASE ORDER NO. ____
REQ. / SPEC. NO. ____
REVISION NO. ____ DATE ____ BY ____
PAGE 7 OF 11

Rev

1 **MISCELLANEOUS CONTINUED**

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection** Nameplate Material (2.4.11.1): ○ **Stainless Steel** ○ Other ____

4 Shipment (4.4.1): ○ Domestic ○ Export ○ Export Boxing Required ○ Commissioning Assistance Required (6.2.16) ○ Mounted on Skid (4.4.1, e)

5 ○ Special Shipping Bearings (4.4.1, k) ○ Outdoor Storage for More Than Six Months (4.4.1) ○ Piping Assembled (4.4.1, h)

6 ○ Electronic Vibration Test Data (4.3.3.15) Digital Format Description: ____ Qty: ____

7 ○ Provide Separate Price For Each Optional Test (6.2.13) Other: ____

8 **MOTOR DATA - FIRST SECTION**

9 ☐ Manufacturer ____ ☐ Type / Model No. ____ ☐ Frame Size / Designation ____

10 Qty. ____ ____ HP ____ RPM (Syn.) ____ Poles ____ Volts ____ Phase ____ Hz

11 Service Factor ____ Insulation Class ____ Temperature Rise Class CLASS B Enclosure ____

12 Rated Speed ____ RPM Full-Load Torque (FLT) ____ ft-lb Rotor WK^2 (6.2.2.1, c) ____ lb-ft^2

13 Locked-Rotor Torque (LRT) ____ % FLT Pull-In Torque (PIT) ____ % FLT Pull-Out Torque ____ % FLT

14 ☐ **Calculated Expected Data (6.2.2.1, f) at the following Loads** Guaranteed Efficiencies

15 Load Point 50% 75% 100% ○ Other: ____ % ○ At 1/4, 1/2, 3/4 and Full Load (6.2.2.1, g)

16 Efficiency ____ % ____ % ____ % ____ % ○ Other ____ %PF; ____ % Load ☐ Efficiency ____ %

17 Power Factor ____ % ____ % ____ % ____ % ▷ Test Method (6.2.2.1, f) ____

18 Current ____ Amps ____ Amps ____ Amps ____ Amps

19 ☐ Motor Speed-Torque (6.2.2.1, a) Curve No. ____ ☐ Motor Speed-Current (6.2.2.1, b) Curve No. ____

20 ☐ Motor Speed-Pulsating Torque (6.2.2.1, a) Curve No. ____ ☐ For Current-Pulsation Operating Cond. (6.2.2.1, f) ____ % Current Pulsation

21 ☐ For Current-Pulsating Operating Condition (6.2.2.1, f) Calculated Efficiency: ____ Calculated Current Pulsation: ____

22 ☐ Rated Motor Field: ____ Amps ____ Volts ○ Calculated Rotor-Response (6.7.2, b) ☐ Curve Nos. (6.7.2, b) ____

23 ☐ Rated Exciter Field: ____ Amps ____ Volts ○ Variable Torque Reciprocating Load (6.2.2.1, h)

24 ☐ Motor Speed-Power Factor Curve No. ____ ☐ Current Variation (6.2.2.1, h) ____ %

25 ☐ Acceleration Curve No. ____ ☐ Efficiency (6.2.2.1, h) ____ % at ____ % Load at ____ % Power Factor

26 ☐ Acceleration Time at Rated Voltage (6.2.2.1, d): ____ sec. ☐ Acceleration Time at Minimum Starting Voltage/MVA (6.2.2.1, d): ____ sec.

27 ☐ Max. Sound Pressure Level (2.1.3) ____ dBA @ 3 ft, no-load ☐ Method of Efficiency Calculation (6.2.2.1, h) ____

28 ☐ Provide Motor Starting Data at 100%, ____ % , & ____ % Voltages

29 ☐ Locked-Rotor Withstand Time, Cold (6.2.2.1, e) at 100% Voltage ____ Sec; at ____ % Voltage ____ Sec.

30 ☐ Locked-Rotor Withstand Time, Rated Temp (6.2.2.1, e) at 100% Voltage ____ Sec; at ____ % Voltage ____ Sec.

31 ☐ Locked-Rotor Current at 100% Voltage ____ Amps: at ____ % Voltage ____ Amps ☐ Locked-Rotor PF ____ %

32 ☐ Weights: Net: ____ lb. Stator ____ lb. Rotor ____ lb. Shipping ____ lb.

33 **Rotor Construction:** ☐ Solid Cylindrical ☐ Laminated Cylindrical ☐ Salient-Pole Solid

34 ☐ Salient-Pole "Star" Punching Type, Shrunk Onto Shaft ☐ Salient-Pole Laminated/Bolted

35 ☐ Salient-Pole Dove-Tail or T-Tail Attachment to Shaft ☐ Other ____

36 ☐ Minimum % Overspeed (2.1.5; 2.4.5.2.7) ____

37 **MOTOR DATA - SECOND SECTION**

38 **Bearings:**

39 Bearing Type Required: ▷ Hydrodynamic (2.4.7.1.1) ▷ Oil Rings Required (2.4.8.1) ▷ Antifriction (2.4.7.1.3)

40 Thrust Bearings, Maximum Connected Equipment Thrust (2.4.7.1.11) ____

41 Bearing, Drive End: Capable of Self-Lube ____ Manufacturer ____ Type ____ Model / Part No. ____

42 Bore Diameter: Min ____ in. Max ____ in. Bore Length ____ in.

43 Design Clearance with Shaft: Min ____ in. Max ____ in. Bearing Loading: ____ PSI

44 Bearing, Non-Drive End: Capable of Self-Lube ____ Manufacturer ____ Type ____ Model / Part No. ____

45 Notes: ____

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 8 OF 11

1 **MOTOR DATA - SECOND SECTION CONTINUED** Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 Bore Diameter: Min ______ in. Max ______ in. Bore Length ______ in.

5 Design Clearance with Shaft: Min ______ in. Max ______ in. Bearing Loading: ______ PSI

6 Thrust Bearing: □ Non-Drive End Manufacturer ______ Type ______ Model / Part No. ______

7 □ Drive End Bearing Loading: ______ PSI

8 ▷ Special Seals for Gas Purge (2.4.7.3) ______

9 ○ Provide Motor Preliminary Parameters With Proposal (6.2.2.3), State Per Unit Values, Motor: ______ kVA Base at Rated Voltage and 77^{0}F

10 □ X_{dv}" Rated Voltage (Saturated) Subtransient Reactance ______

11 □ X_{2v} Rated Voltage (Saturated) Negative-Sequence Reactance ______

12 □ T_{a3} Rated Voltage (Saturated) Armature Time Constant ______ Sec.

13 □ Rated MVA ______ □ Rated Terminal Voltage ______ kV

14 ▽ **Motor Parameters (State Per Unit Values, Motor** ______ **kVA Base at Rated Voltage and 77°F):**

15 X_l Armature Leakage Reactance ______

16 X_{ad} Direct Axis Armature Reactance ______

17 X_d Direct Axis Synchronous Reactance (Saturated) ______ Un-Saturated ______

18 X_p Potier Reactance ______

19 X'_d Direct Axis Transient Reactance (Saturated) ______ Un-Saturated ______

20 X''_d Direct Axis Subtransient Reactance (Saturated) ______ Un-Saturated ______

21 X_{aq} Quadrature Axis Armature Reactance ______

22 X_q Quadrature Axis Synchronous Reactance (Saturated) ______ Un-Saturated ______

23 X_f Field Leakage Reactance ______

24 X'_q Quadrature Axis Transient Reactance (Saturated) ______ Un-Saturated ______

25 X''_q Quadrature Axis Subtransient Reactance (Saturated) ______ Un-Saturated ______

26 X_{kq} Quadrature Axis Amortisseur Reactance (Slip = 1.0) ______

27 X_{kd} Direct Axis Amortisseur Reactance (Slip = 1.0) ______

28 X_2 Negative Sequence Reactance (Saturated) ______ Un-Saturated ______

29 R_a Stator Armature Resistance/Phase ______

30 R_f Field Resistance (Without FDRs) ______

31 R_{fr} Field Resistance (With FDRs) ______

32 R_{kq} Quadrature Axis Amortisseur Resistance (Slip = 1.0) ______

33 R_{kd} Direct Axis Amortisseur Resistance (Slip = 1.0) ______

34 R_1 Positive Sequence Resistance ______

35 R_2 Negative Sequence Resistance ______

36 T_a Armature Short-Circuit Time Constant, Sec ______

37 T'_{do} Direct Axis Transient Open-Circuit Time Constant, Sec ______

38 T'_{qo} Quadrature Axis Transient Open-Circuit Time Constant, Sec ______

39 T''_{do} Direct Axis Subtransient Open-Circuit Time Constant, Sec ______

40 T''_{qo} Quadrature Axis Subtransient Open-Circuit Time Constant, Sec ______

41 T'_d Direct Axis Transient Short-Circuit Time Constant, Sec ______

42 T''_d Direct Axis Subtransient Short-Circuit Time Constant, Sec ______

43 P_r Synchronizing Torque Coefficient, kW/Radian (For reciprocating loads only) ______

44 C_w Winding Capacitance to Ground, Microfarads/Phase ______

45 I_2^2t Limit ______

	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 9 OF 11

STATOR AND ROTOR WINDING REPAIR DATA Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

▽ **Stator Coil Information:**

Total Copper Weight ______ lb. Copper Strand Size ______ Insulation ______

Number of Strands per Coil Turn ______ Turn Insulation Description ______

Number of Turns per Coil ______ Coil Ground-Wall Insulation Description ______

Coil Configuration ______ Rows by ______ Columns

Finished Coil Dimension in Slot Region, W x H x L (Also Give Tolerances): ______

Total Number of Stator Slots ______ Winding Throw ______ Winding Connection ______

Slot Filler Description - Thickness: Top ______ Side ______ Between Top-Bottom Coils ______

Stator Bore Diameter ______ Slot Dimensions ______ Stress Grading if Applicable ______

Special End-Turn Bracing ______

Coil Dimensional Drawing No. ______ Thickness Groundwall Insulation ______ mils

Thickness Turn Insulation ______ mils Thickness Strand Insulation ______ mils

Other: ______

▽ **Rotor Winding Information:**

Total Copper Weight ______ lb. Strand or Bar Size ______ Conductor Material ______

Insulation Description ______

General Description of Winding (Number of Turns, Formed Coil, size, Etc,) ______

______

Damper Winding Description, If Applicable ______

______

Retaining Ring Alloy, If Applicable ______

Ring Material ______ Ring Dimensions Premachining ______

Shaft Material ______

Other: ______

______

MISCELLANEOUS

SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 10 OF 11

1	**ANALYSIS, SHOP INSPECTION, AND TESTS**				Rev
2	NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**				
3	**Bold Type Indicates Typical Selection**				
4	**Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The**				
5	**Purchaser In the Notes Section Below.**				
6		**Required**	**Witnessed**	**Observed**	
7	**Acceptance Criteria (2.1.13; 6.7.2, a):**	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**	
8	**Coordination Meeting (6.3)**	●			
9	Design Review (6.5)	○			
10	Torsional Analysis (2.4.6.2.7) By ______	○			
11	Lateral Critical Speed Analysis (2.4.6.2.1)	○			
12	Review of Quality Control Program (4.2.3.4)	○			
13	Submit Test Procedures 6 Weeks Before Tests (4.3.1.5)	○			
14	Inspection for Cleanliness per API 614 (4.2.3.2; 4.2.3.3)	○	○	○	
15	Observance of Assembly/Dismantling (4.3.1.1)	○	○	○	
16	Demonstrate Accuracy of Test Equipment (4.3.1.16)	○	○	○	
17	Stator Core Test (4.3.4.1)	○	○	○	
18	Surge Comparison Test (4.3.4.2)	○	○	○	
19	Special Surge Test of Coils (4.3.4.2.1)	○	○	○	
20	Sacrifical Coils Cut Into Segments (4.3.4.2.1, c)	○	○	○	
21	Number of Segments Cut Each Coil ___ Cuts in: Straight Section ___ Bends ___				
22	Partial Discharge Test (4.3.4.6)	○	○	○	
23	Balance in Minimum of 3 Planes (2.4.6.3.1)	○	○	○	
24	**Dynamic Balance Rotors 600 rpm and Above (2.4.6.3.1)**	●	○	○	
25	Final Balance (4.3.1.6)	○	○	○	
26	Component Balance for > 4 Pole (2.4.6.3.1)	○	○		
27	Residual Unbalance Verification Test (2.4.6.3.6)	○	○	○	
28	Balance Check with Half Coupling (2.4.6.3.3)	○	○	○	
29	Running Tests with Coupling Half (2.4.6.3.3; 4.3.1.6)	○			
30	Stator Inspection Prior to VPI (4.3.4.5)	○	○	○	
31	Sealed Winding Conformance Test (4.3.4.4)	○	○	○	
32	Power Factor Tip-Up Test (4.3.4.3)	○	○	○	
33	**Routine Test (4.3.2)**	●	○	○	
34	Insulation Resistance Using Table 7 (4.3.2.1, d)	○	○	○	
35	Bearing Dimensional & Alignment Checks Before Tests (4.3.2.1, j)	○	○	○	
36	Bearing Dimensional & Alignment Checks After Tests (4.3.2.1, k)	○	○	○	
37	Vibration Monitoring and Recording (4.3.3.6; 4.3.3.8)	○	○	○	
38	Complete Test (4.3.5.1.1)	○	○	○	
39	Efficiency (4.3.5.1.1, a)				
40	Locked Rotor (4.3.5.1.1, b)				
41	Open/Short-Circuit Saturation (4.3.5.1.1, c)				
42	Heat Run (4.3.5.1.1, d)				
43	Exciter Heat Run (4.3.5.1.1., e)				
44	No Load V-Curve (4.3.5.1.1, f)				
45	Sound Pressure Level Test (4.3.5.1.1, g)				

	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 11 OF 11

ANALYSIS, SHOP INSPECTION, AND TESTS CONTINUED

Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The Purchaser In the Notes Section Below.

	Required	**Witnessed**	**Observed**
Acceptance Criteria (2.1.13; 6.7.2, a):	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**
DC High-Potential Test (4.3.5.1.2)	○	○	○
Torque Pulsations During Starting	○	○	○
Rated Rotor Temperature-Vibration Test (4.3.5.2.1)*	○	○	○
*(For Motors Not Receiving Complete Test)			
Unbalance Response (4.3.5.3)	○	○	○
Bearing Housing Natural Frequency Test (4.3.5.4)	○	○	○
Certification of Materials (4.2.1.1, a)	○	○	○
Final Assembly Running Clearances (4.2.1.1, e)	○	○	○
Material Inspection (4.2.2)	○	○	○
Radiographic Test (4.2.2.2) Parts ______	○	○	○
Ultrasonic Test (4.2.2.3) Parts ______	○	○	○
Ultrasonic inspection of shaft forging (2.4.5.1.8)	○	○	○
Magnetic Particle Test (4.2.2.4) Parts ______	○	○	○
Liquid Penetrant Test (4.2.2.5) Parts ______	○	○	○
Certified Data Prior to Shipment (4.3.1.15; 6.7.2, a)	○	○	○
Burn-in Testing of Rotating Element Mounted Electronic Components (2.5.3.3)	○	○	○
Heat Exchanger Performance Verification Test (TEWAC Enclosures) (4.3.5.5)	○	○	○
Pulsating Torque Tests for 4 & 6 Pole Machines (4.3.5.1.3)	○	○	○
Other: ______	○	○	○
______	○	○	○

NOTES

SYNCHRONOUS MOTOR
API 546 3RD Edition -- DATA SHEETS
METRIC UNITS

JOB NO. ______ ITEM / TAG NO. ______
PURCHASE ORDER NO. ______
REQ. / SPEC. NO. ______
REVISION NO. ______ DATE ______ BY ______
PAGE 1 OF 11

Rev

FOR / USER ______ DRIVEN EQUIPMENT ______
SITE / LOCATION ______ QUANTITY ______
SUPPLIER ______ ▽ SUPPLIER PROJECT NO. ______
ITEM NAME ______
Applicable To: ○ Proposal ○ Purchase ○ As Built

GENERAL

NOTE: (Alpha key code) ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Basic Data:

Applicable Standards (1.3.1; 1.3.2; 1.6): ○ **North American (i.e., ANSI, NEMA)** ○ International (i.e., IEC, ISO)
Nameplate Power (2.2.1.1): ______ kW ______ **Service Factor (2.2.1.3)** ______ RPM (Synchronous)
______ Volts (2.2.1.2) ______ Phase ______ Hertz Duty: ○ Continuous ○ Other ______
Rated PF: ______ Insulation Class: ______ Voltage and Frequency Variations (2.2.1.2.1) ______
Motor Power Source: ○ Sine Wave Power ○ ASD Power ○ LCI Power
Stator Temperature Rise (2.3.1.1) ______ °C Above ______ °C By RTD
Rotor Temperature Rise ______ °C Above ______ °C By Resistance ○ Sealed Exciter Windings Required (2.3.1.6)
□ Manufacturer's Type ______ □ Frame Size ______
Other: ______

Site Data (2.1.2):

Area Classification (2.1.8): ○ Nonclassified ○ Classified as: Class ______ Group ______ Division ______ Autoignition Temp ______ °C
Class ______ Group ______ Zone ______ Temperature Code ______
Maximum Sound Pressure Level (2.1.3): ○ **85 dBA @ 1 m. NO-LOAD, FULL VOLTAGE/FREQUENCY, SINE WAVE POWER** ○ ______ dBA
Ambient Temperature: Max ______ °C Min ______ °C
Relative Humidity: Max ______ % Min ______ %
Motor Location: ○ Indoor ○ Outdoor Roof Over Motor: ○ Yes ○ No
Building Temperature Controlled: ○ Yes ○ No Site Elevation: ______ m
Nonmassive Foundation (2.4.6.1.2), Description ______

Unusual Conditions:

Dust (2.4.1.2.2,c) ______ Chemicals (2.1.2) ______
Seismic Loading (2.4.2.2) ______ Corrosive Agents (2.4.10.1.2) ______
Other: ______

Explosion Protection Labeled Motors

Explosion Protection Standard Label ○ Ex (Canada) ○ EEx (CENELEC) ○ AEx (US) ○ Other ______
○ Ex n (Non-Sparking) ○ Ex p (Pressurization) ○ Ex d (Flameproof) ○ Other ______
○ Third Party Certification Required ○ ATEX ○ Other ______

Enclosure (2.4.1.2.1)

○ Weather Protected (WP) (2.4.1.2.2) ○ Type 1 ○ Type II
Air Filters: ○ Provision Only (3.5.2) ○ Required (3.5.4) ○ **90%, 10 µm** ○ Other ______
▷ Manufacturer ______ ▷ Type ______ ▷ Model ______
Differential Pressure Switch (3.5.5): ○ Provision Only ○ Required ○ Differential Pressure Guage (3.5.5)
▷ Manufacturer ______ ▷ Type ______ ▷ Model ______
○ Explosion Proof ○ TEFC (2.4.1.2.3) ○ Drip Proof Guarded ○ TEPV (2.4.1.2.3) ○ Other ______
○ TEAAC (2.4.1.2.3) Tube Materials (2.4.10.8,a): ○ Copper ○ Copper Alloy
○ Aluminum Alloy ○ Stainless Steel ○ Other ______

Notes: ______

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 2 OF 11

GENERAL (CONTINUED) Rev

NOTE: **(Alpha key code)** TO BE COMPLETED BY PURCHASER **(m or l)** BY MANUFACTURER WITH PROPOSAL **(o or n)** BY MANUFACTURER AFTER ORDER **(s or q)** BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

TEWAC (2.4.1.2.4) Tube Materials (2.4.10.8, b): **Cu-Ni** Other ______

Redundant Coolers (2.4.1.2.4, b): Yes No Exchanger Location/Orientation (2.4.1.2.4, c) ______

Cooling Water Conditions per 2.4.1.2.4, a: Yes No (Other) ______

Water Flow (l/m) Max ______ Min ______ Water Pressure (kPa) Max ______ Min ______

Tube Construction (2.4.1.2.4, d; 2.4.10.8, c): **Single Tube** Double Tube

Flow Sensor Local Indicator Required (2.4.1.2.4, g) Relay Contacts: NO NC

Air Temperature Sensor Required (2.4.1.2.4, h), Type ______

Leak Detection Required **Inner** Outer Type and Description ______

High Flow Alarm Set Point ______ l/m Low Flow Shutdown Set Point ______ l/m

Provision for Pre-Start Purging (2.4.1.1, e) ______ Marine Grade Stainless Steel Fasteners (2.4.1.1, c)

Degree of Protection IP (2.4.1.2.1) IP ______ Method of Cooling IC (2.4.1.2.1) IC ______

Other: ______

Mounting:

Horizontal: Foot Mounted Flange Mounted Flange Details ______

Vertical: Shaft Up Shaft Down P-base Flange Diameter ______

Pedestal Axial Stator Shift Required (2.4.2.15)

Engine Type Bearings Furnished By ______ Shaft Furnished By ______

Baseplate: Furnished By (2.4.2.6): ______ Soleplate: Furnished By (2.4.2.6): ______

Special Connections for Field Piping (2.4.3.1): ______

When Rotor Dynamic Analysis Is Specified, List of Foundation Data Required From Purchaser (2.4.6.1.2): ______

______

______

Electrical System:

Primary Power Source ______ Volts ______ Phase ______ Hertz Maximum Ground Fault ______ Amps

Method of System Grounding (3.6.2.3) Resistance Reactance Ungrounded Solid

Fault Current at Machine Terminals (3.1.2) ______ MVA Let-Through Energy (3.1.2): ______ I^2t (Ampere-squared seconds)

Min S.C. at Motor Bus (2.2.4.2, c) ______ MVA at ______ kV_{base} X/R Ratio: ______

Other: ______

Motor Starting (2.2.4): **ACROSS-THE-LINE STARTING AT 80% OF RATED VOLTAGE (2.2.4.1)**

Loaded Unloaded Partially Loaded ______ % Starting Torques in Excess of IEC or NEMA (2.2.3.1) ______ %

Load Reacceleration Required (2.2.3.2, b): No Yes Reacceleration Curve No. ______

If Yes, Complete the Following: Max Voltage Interruption ______ Sec. Voltage at Motor Terminals ______ Volts

Other Starting Method (2.2.4.2, a) Type ______ Reduced Voltage ______ Volts

Starting Capability Data (2.2.4.2, b): Min. ______ Volts at Machine Terminals Under ______ Amps Inrush Current

or (2.2.4.2, c): Min. S.C. kVA ______ and ______ X/R ratio and ______ Volts at Machine Terminals

Number of Full Voltage Starts if Not 5000 (2.2.5.1; 2.4.5.1.1): ______ Consecutive Starts Different From Table 4 (2.2.5.2): ______

Notes; ______

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 3 OF 11

Rev

GENERAL (CONTINUED)

NOTE: **(Alpha key code)** — TO BE COMPLETED BY PURCHASER **(m or l)** — BY MANUFACTURER WITH PROPOSAL **(o or n)** — BY MANUFACTURER AFTER ORDER **(s or q)** — BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Adjustable Speed Drive Conditions (2.1.5):

ASD — ASD with DOL Start — Bypass @ Utility Frequency

Variable Torque Speed Range: Min Speed ______ RPM ______ N-m Max. Speed ______ RPM ______ N-m

Constant Torque Speed Range: Min Speed ______ RPM Max. Speed ______ RPM ______ N-m

Constant Power Speed Range: Max Speed ______ RPM ______ N-m

Other: ______

Bearings:

Bearing Type: **Hydrodynamic (2.4.7.1.1)** — Split Sleeve (2.4.7.1.2) — Tilting Pad (2.4.7.1.2) — Oil Ring Required (2.4.8.1)

Antifriction (2.4.7.1.3)

Thrust Bearing (2.4.7.1.5) Max Driver Thrust Downthrust Momentary ______ kg Upthrust Momentary ______ kg

Continuous ______ kg Continuous ______ kg

Bearing Constant-Level Sight Feed Oilers Required (2.4.7.2.2) Type: ______

Special Seals for Gas Purge (2.4.7.3.a) — Non-conducting Seals (2.4.7.3, b)

Other: ______

LUBRICATION SYSTEM

SELF-LUBE (2.4.8.1) — Pressurized Lube Required (2.4.8.1) System Supplied By (2.4.8.4): ______ — Common With Driven Equipment

Per API 614: ______ -purpose oil system (2.4.8.6) — Main Oil Pump Required: — Integral Shaft Driven — Separate

Oil Rings Not Provided

Type/Viscosity of Oil (2.4.8.8) ______ — Pressure (2.4.8.4; 2.4.8.5) ______ kPa

Total Bearing Oil Requirements (6.2.3): ______ l/m ______ kPa — Heat Loss To Be Removed ______ kW

Antifriction Bearings: Grease: Type ______ Oil Mist (2.4.7.4.1) — Pure mist — Purge mist

Other: ______

SPECIAL CONDITIONS:

Shaft and Spider one piece forging for 4 or more poles (2.4.5.1.2, b; 2.4.5.1.4)

Special Vibration Requirements (4.3.3.10) ______

Efficiency Evaluation Factor (EF) (6.2.1) ______ (value) ______ (currency) /kW applied at ______ % of F.L.

National, State / Provincial, or Local Codes (2.1.8): ______

External Forces on Motor Housing That May Affect Site Performance (2.1.13; 2.4.4): ______

Special Overspeed Requirement (2.4.5.2.7): ______

Other: ______

MAIN CONDUIT BOX

Main Terminal Box (3.1.1):

Box Location ______ Conductor Size ______ Type ______ Insulation ______ Qty. Per Phase ______

Quick Disconnect Type Bushing Studs or Receptacles (3.1.6, f) ______

Space for Termination of Shielded Cables (3.1.6, e) Cable Entering From (3.1.4): Top — Bottom — Drive Side — Non-Drive End Side

Both Ends of Stator Winding Brought Out To Terminal Box (2.2.2.2) — Thermal Insulation (3.1.6, a)

Cable Between Stator Windings and Main Terminals (2.3.1.11): Yes — No Description: ______

Space Heaters (3.1.6, b): Temp. Code ______ ______ Volts ______ Phase ______ Hz ______ kW

Differential Protection Current Transformers (2.2.2.2; 3.1.6, h; 3.1.8; 3.6.3): Accuracy Class ______ Ratio ______ Quantity ______

Type: Self-balancing — Full Differential — Supplied By ______ — Mounted By ______

Notes: ______

API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 4 OF 11

1 **MAIN CONDUIT BOX (CONTINUED)** Rev

2 NOTE: **(Alpha key code)** TO BE COMPLETED BY PURCHASER **(m or l)** BY MANUFACTURER WITH PROPOSAL **(o or n)** BY MANUFACTURER AFTER ORDER **(s or q)** BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 Surge Capacitors (3.1.6, g; 3.6.2.1): Microfarads ____ Supplied By ____ Mounted By ____

5 Surge Arresters (3.1.6, g; 3.6.2.2): kV Rated ____ Supplied By ____ Mounted By ____

6 Current Transformers (3.1.6, h) for Ammeter Accuracy Class ____ Ratio ____ Quantity ____

7 Supplied By ____ Mounted By ____

8 Potential Transformers (3.1.6, j) for Voltmeter Accuracy Class ____ Ratio ____ Quantity ____

9 Fuses Required Supplied By ____ Mounted By ____

10 Provision for Purging (3.1.6, c)

11 Removable Links (3.1.6, d) Silver- or Tin- Plated Bus Joints (3.1.6, i) Ground Bus (3.1.6, k)

12 Insulated Terminations and Interior Jumpers (3.1.6, m) Other: ____

13 **ACCESSORIES**

14 **Frame Space Heaters (3.4):** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase ____ kW

15 **Bearing Heaters (2.4.8.3):** Temp. Code ____ Type ____ ____ Volts ____ Phase ____ kW

16 **Exciter Space Heaters:** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase ____ kW

17 **Winding Temperature Detectors (3.2.1):** **Three Per Phase, 3 Wire Platinum, 100 Ohms at 0°C** Ground One Common Lead (3.2.1.2)

18 Other Detector: Qty / Phase ____ Type ____ Material ____ Wires ____

19 Thermocouples: Qty / Phase ____ Type ____

20 Recommended Settings: Alarm ____ °C Shutdown ____ °C

21 **Monitors and Devices** Monitor for Shaft Grounding Brush Replacement (2.4.7.1.9)

22 Test Device For Rotating Electronic Components (2.5.3.8) Rotating Diode Failure Detection (2.5.3.12)

23 Online Rotor Monitoring System (2.5.3.10): Description: ____

24 **Exciter Power Supply** Permanent Magnet Generator (2.5.3.13) Constant Voltage Transformer (2.5.1.5) Phase Controlled Rectifier (2.5.1.5)

25 Other (2.5.1.5) ____

26 **Auxiliary Equipment Enclosures (3.1.4):** Box Location (Facing Opposite Drive End) ____

27 Conduit/Cable Entry From: Bottom Other: ____

28 **Hydrodynamic & Thrust Bearing Temperature Devices (3.3):**

29 Provision Only Install per API 670 (3.3.1) Other ____

30 **RTD's (3.3.1)** Qty / Brg. ____ Type ____ Material ____ Wires ____ Ground One Common Lead (3.2.1.2)

31 Thermocouple: Qty / Brg. ____ Type ____ Material ____ Wires ____

32 Dial Type Thermometers (2.4.7.1.16): Type ____ Alarm Contacts Number of Contacts ____ NO NC

33 Location of Bearing Temperature Sensor Wire Terminations: Terminal box at motor side In the Stator RTD T Box Conduit Head at Bearing

34 Bearing Temperature Recommended Settings: Alarm ____ °C Shutdown ____ °C

35 Thrust Bearing Temp. Recommended Settings: Alarm ____ °C Shutdown ____ °C

36 **Vibration Detectors (3.8):** **Motors 1200 rpm and higher** Installed Qty / Bearing: **TWO (3.8.1)** Four (3.8.2)

37 Phase Reference Probe (3.8.1): Provisions Only **INSTALLED**

38 **Motors less than 1200 rpm** Installed Qty / Bearing: Two (3.8.1) Four (3.8.2)

39 Phase Reference Probe (3.8.1): Provisions Only Installed

40 Vibration Probe Leads Protected by (3.8.1.1; 3.9.1; 3.9.2): Liquidtight Flexible Metal Conduit, Length ____ m

41 Other Description: ____

42 Probe, Oscillator-Demodulator Mfr. ____ Model / Series ____

43 Probe Supplied By ____ Installed by ____ Osc.-Demod. Furnished By ____ Installed by ____

44 Bearing Housing Seismic Sensors (3.8.3) Provisions Only Installed Sensor Type ____ Sensor Mfr. ____

45 Qty / D.E. Bearing ____ Location (H, V, A) ____ Qty / N.D.E. Bearing ____ Location (H, V, A) ____

	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 5 OF 11

1 **ACCESSORIES (CONTINUED)** Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 ▷ Sensor Supplied By ______ Installed by ______ ▷ Transducer Furnished By ______ Installed by ______

5 Location of Vibration Sensor Wire Terminations: ▷ Terminal box at motor side ▷ Within Sensor Housing ▷ Other ______

6 Vibration Switch: ○ Manual Reset ○ Electric Reset Switch Type: ______ Model: ______

7 Terminal Head or Box (3.1.11) ______

8 **Alarm and Control Switches (3.6.1): SPDT 10 Amp 115 Volt** ○ DC Rated Contacts: ______ ○ **AC Rated Contacts:** ______

9 **Partial Discharge Detectors (3.6.4; 3.1.6, l)** ○ Yes Describe Required System: ______

10 ______

11 **Separately Powered Auxiliary Fan(s) (2.4.10.6.3): Driver Information (where applicable)** ▷ Standard No. ______

12 Quantity ______ Location ______ Encl. ______ kW ______ RPM ______ ______ Volts ______ Phase ______ Hertz

13 Quantity ______ Location ______ Encl. ______ kW ______ RPM ______ ______ Volts ______ Phase ______ Hertz

14 Other: ______

15 ______

16 **CONTROLS**

17 **Motor Vendor to Furnish**

18 ○ Manufacturer's Standard Excitation Control (Including Application & Protection) Package for Mounting in:

19 ○ Purchaser's Switchgear ○ Vendor Furnished Control Panel

20 ○ Separate Control Devices, as Checked, for Mounting in:

21 ○ Purchaser's Switchgear ○ Vendor Furnished Control Panel

22 ○ Completely Assembled Control Panel with Devices as Checked (3.6.5.2)

23 **Devices Mounted on Front of Panel, Labeled as Indicated**

24 ○ Motor "Start-Stop" Switch ○ Pilot Lights: ○ "RUN" ○ "STOP" ○ "READY"

25 ○ Ammeter (0 - 5 A), 0 - ______ A Scale, "MOTOR AMPERES"

26 ○ Voltmeter (0 - 150 VAC), 0 - ______ kV Scale, "MOTOR VOLTAGE"

27 ○ "POWER FACTOR" Meter, 0.80 - 1 - 0.80 Scale or ______ - ______ - ______ Scale

28 ○ Ammeter, 0 - ______ Amps Scale, "EXCITER FIELD AMPERES"

29 ○ Rheostat, 0 - ______ VAC, Scale ______ A, "EXCITER FIELD"

30 ○ Potentiometer, "EXCITER FIELD" ○ "EXCITER FIELD ON-OFF" Test Switch

31 ○ Timer, 0 Sec - ______ Sec, On Delay, "INCOMPLETE SEQUENCE"

32 ○ Timer, 0 Sec - ______ Sec, On Delay, "OUT-OF-STEP"

33 ○ Overcurrent Relays (3), Instantaneous, 0.5 - 2 A Range, "DIFFERENTIAL PROTECTION": Type: ______

34 ○ Other ______

35 ○ Overtemperature Relay, 50 - 190 ^{O}C Range, For Use with ______ Ohm RTD, "STATOR TEMPERATURE"

36 Quantity ______ Type ______

37 ○ Alarm Panel ○ Automatic Power-Factor Controller (2.5.1.3) ○ VAR Controller (2.5.1.3)

38 ○ Vibration Probe Monitors: Manufacturer ______ Model ______

39 ○ Temperature Indicator, ______ ^{O}C

40 ○ Other ______

41 **Devices Mounted Inside Panel, Labeled to Coincide with Drawing Identification:**

42 ○ Control Power Transformer, Constant Voltage, ______ kVA, ______ V - 120 V Rated to Maintain 95 % Secondary Voltage with 50% Sag

43 of Primary Voltage (2.5.1.5) ○ Phase Controlled Rectifier (2.5.1.5)

44 ○ Other (2.5.1.5) ______

45 Notes: ______

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 6 OF 11

CONTROLS (CONTINUED)

Rev

NOTE: (Alpha key code) — ○ TO BE COMPLETED BY PURCHASER **(m or l)** — □ BY MANUFACTURER WITH PROPOSAL **(o or n)** — ▽ BY MANUFACTURER AFTER ORDER **(s or q)** — ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

○ Full-Wave Bridge, Silicon Rectifiers ______ A (Min of 125 % of Exciter Field Amperes), Convection Cooled

○ Contactor Exciter Field Current

○ Field Monitor Relay, to Switch and Signal on Loss of Field or Out of Step Condition

○ Auxiliary and Timing Relays, as Required ○ Surge Suppressors and Fuses, as Required

○ Terminal Blocks, Heavy Duty, Identified by Unique Numbers, Number as required with 20 % Spares ______

○ Switches required for Alarm and Control devices (3.6.1): Contacts: **AC** ______ DC ______

○ Control Panel Wiring Entrance: ○ Top ○ Bottom ○ Side

○ Other: ______

DRIVEN EQUIPMENT INFORMATION

Driven Equipment: Tag No. ______ Description ______ Location ______

Type of Load: Centrifugal: ○ Compressor ○ Pump ○ Fan ○ Other ______

Positive Displacement: ○ Reciprocating Compressor: Compressor Factor "C" ______

Maximum Current Pulsation (NEMA Defined) (2.2.6.1, c): ○ 40% ○ 66% ○ Other: ______

○ Calculated Efficiency Based on Current-Pulsation Operating Conditions (6.2.2.1, h) ______

Driven Equipment Mfr. ______ Type / Model No. ______ RPM ______

Load Speed-Torque Curve No. (2.2.3.2 a) ______ Crank-Effort Chart or Torque-Effort Curve No. (6.2.2.1, h) ______

Total Driven-Equipment GD^2 (2.2.3.2, c) ______ kg-m^2 at ______ RPM

Driver Connection to Load: ○ Direct Coupled ○ V-Belt Connection ○ Through Gearbox

Speed-Increasing-Reducing Gear (2.2.3.2, c): Ratio ______ Gear GD^2 (2.2.3.2, c) ______ kg-m^2 at ______ rpm

Motor Shaft Extension (2.4.5.1.9): ○ Cylindrical Fit ○ Taper Fit ○ Flange

Rotation ***Viewed from Non Drive End of Motor:*** ▷ Clockwise ▷ Counterclockwise ▷ Bi-directional

Coupling (2.4.9.4): Type ______

○ Manufacturer's Standard ○ Per API 671 Mfr. ______ Type / Model ______

Coupling GD^2 (2.2.3.2, c) ______ kg-m^2 at ______ rpm Mass Moment of Coupling Half (2.4.6.2.2, f) ______ kg-m^2

Supplied By: ○ Motor Mfr ○ Driven Equipment Mfr ○ Purchaser ○ Others ______

Mounted By: ○ Motor Mfr ○ Driven Equipment Mfr ○ Purchaser ○ Others ______

Other: ______

MISCELLANEOUS

○ Manufacturer's Standard Paint ○ Extra Coat at Shipment ○ User's Special Paint ______ ○ Outline for Special Weather Protection (6.2.14)

○ Proof of Nonsparking, Corrosion-Resistant Fan (2.4.10.6.1) ○ Quantity of Special Tools and Lifting Required (2.1.12; 2.4.2.13): ______

▷ Special Low-Temp Material Requirements (2.4.10.4) ______

▷ Special Winterizing Requirements (6.2.14) ______

○ Materials To Be Identified With ANSI, ASTM, or ASME Numbers (6.2.17) ______

○ Typical Drawings & Literature with Proposal ○ Electronic Instruction Manuals (6.6.1) Qty: ___ ○ Photos showing assembly steps required (6.8.5)

○ Performance Curves Supplied in Digital Format (6.6.1) Digital Format Description: ______

○ Manufacturer To Supply Curve Data in Tabular Format (6.6.1) ○ NRTL Certification (6.8.6) Qty: ___ ○ PMI Certification (6.8.6) Qty: ___

○ Detailed instructions and photographs for disassembly and inspection (6.8.4, c) Qty: ___ ○ Certified Drawings (6.6.2) Qty: ___

○ Type Tests and Design Information Verifying All Gasket Materials are Impervious to Lube Oil and Chemicals (3.1.4), Qty of Type Tests Documentation ___

○ Special Identification for Transmittals (6.4.2, e) ○ Separate Nameplate with Purchaser's Information (2.4.11.4)

______ ______

______ ______

Notes: ______

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 7 OF 11

1 **MISCELLANEOUS (CONTINUED)** Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection** Nameplate Material (2.4.11.1): ○ **Stainless Steel** ○ Other ______

4 Shipment (4.4.1): ○ Domestic ○ Export ○ Export Boxing Required ○ Commissioning Assistance Required (6.2.16) ○ Mounted on Skid (4.4.1, e)

5 ○ Special Shipping Bearings (4.4.1, k) ○ Outdoor Storage for More Than Six Months (4.4.1) ○ Piping Assembled (4.4.1, h)

6 ○ Electronic Vibration Test Data (4.3.3.15) Digital Format Description: ______ Qty: ___

7 ○ Provide Separate Price For Each Optional Test (6.2.13) Other: ______

8 **MOTOR DATA - FIRST SECTION**

9 □ Manufacturer ______ □ Type / Model No. ______ □ Frame Size / Designation ______

10 Qty. ___ ______ kW ______ RPM (Syn.) ______ Poles ______ Volts ______ Phase ______ Hz

11 Service Factor ______ Insulation Class ______ Temperature Rise Class CLASS B Enclosure ______

12 Rated Speed ______ RPM Full-Load Torque (FLT) ______ N-m Rotor GD^2 (6.2.2.1, c) ______ kg-m^2

13 Locked-Rotor Torque (LRT) ______ % FLT Pull-In Torque (PIT) ______ % FLT Pull-Out Torque ______ % FLT

14 □ **Calculated Expected Data (6.2.2.1, f) at the following Loads** Guaranteed Efficiencies

15 Load Point 50% 75% 100% ○ Other: ______ % ○ At 1/4, 1/2, 3/4 and Full Load (6.2.2.1, g)

16 Efficiency ______ % ______ % ______ % ______ % ○ Other ___ %PF; ___ % Load □ Efficiency ___ %

17 Power Factor ______ % ______ % ______ % ______ % ▷ Test Method (6.2.2.1, f) ______

18 Current ______ Amps ______ Amps ______ Amps ______ Amps

19 □ Motor Speed-Torque (6.2.2.1, a) Curve No. ______ □ Motor Speed-Current (6.2.2.1, b) Curve No. ______

20 □ Motor Speed-Pulsating Torque (6.2.2.1, a) Curve No. ______ □ For Current-Pulsation Operating Cond. (6.2.2.1, f) ______ % Current Pulsation

21 □ For Current-Pulsating Operating Condition (6.2.2.1, f) Calculated Efficiency: ______ Calculated Current Pulsation: ______

22 □ Rated Motor Field: ______ Amps ______ Volts ○ Calculated Rotor-Response (6.7.2, b) □ Curve Nos. (6.7.2, b) ______

23 □ Rated Exciter Field: ______ Amps ______ Volts ○ Variable Torque Reciprocating Load (6.2.2.1, h)

24 □ Motor Speed-Power Factor Curve No. ______ □ Current Variation (6.2.2.1, h) ___ %

25 □ Acceleration Curve No. ______ □ Efficiency (6.2.2.1, h) ___ % at ___ % Load at ___ % Power Factor

26 □ Acceleration Time at Rated Voltage (6.2.2.1, d): ___ sec. □ Acceleration Time at Minimum Starting Voltage/MVA (6.2.2.1, d): ___ sec.

27 □ Max. Sound Pressure Level (2.1.3) ___ dBA @ 1 m, no-load □ Method of Efficiency Calculation (6.2.2.1, h) ______

28 □ Provide Motor Starting Data at 100%, ______ % , & ______ % Voltages

29 □ Locked-Rotor Withstand Time, Cold (6.2.2.1, e) at 100% Voltage ______ Sec; at ______ % Voltage ______ Sec.

30 □ Locked-Rotor Withstand Time, Rated Temp (6.2.2.1, e) at 100% Voltage ______ Sec; at ______ % Voltage ______ Sec.

31 □ Locked-Rotor Current at 100% Voltage ______ Amps: at ______ % Voltage ______ Amps □ Locked-Rotor PF ______ %

32 □ Weights: Net: ______ kg Stator ______ kg Rotor ______ kg Shipping ______ kg

33 **Rotor Construction:** □ Solid Cylindrical □ Laminated Cylindrical □ Salient-Pole Solid

34 □ Salient-Pole "Star" Punching Type, Shrunk Onto Shaft □ Salient-Pole Laminated/Bolted

35 □ Salient-Pole Dove-Tail or T-Tail Attachment to Shaft □ Other ______

36 □ Minimum % Overspeed (2.1.5; 2.4.5.2.7) ______

37 **MOTOR DATA - SECOND SECTION**

38 **Bearings:**

39 Bearing Type Required: ▷ Hydrodynamic (2.4.7.1.1) ▷ Oil Rings Required (2.4.8.1) ▷ Antifriction (2.4.7.1.3)

40 Thrust Bearings, Maximum Connected Equipment Thrust (2.4.7.1.11) ______

41 Bearing, Drive End: Capable of Self-Lube ______ Manufacturer ______ Type ______ Model / Part No. ______

42 Bore Diameter: Min ______ mm Max ______ mm Bore Length ______ mm

43 Design Clearance with Shaft: Min ______ mm Max ______ mm Bearing Loading: ______ kPa

44 Bearing, Non-Drive End: Capable of Self-Lube ______ Manufacturer ______ Type ______ Model / Part No. ______

45 Notes: ______

energy API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS
	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 8 OF 11

Line	MOTOR DATA - SECOND SECTION (CONTINUED)	Rev
1	**MOTOR DATA - SECOND SECTION (CONTINUED)**	
2	NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**	
3	**Bold Type Indicates Typical Selection**	
4	Bore Diameter: Min ______ mm Max ______ mm Bore Length ______ mm	
5	Design Clearance with Shaft: Min ______ mm Max ______ mm Bearing Loading: ______ kPa	
6	Thrust Bearing: ☐ Non-Drive End Manufacturer ______ Type ______ Model / Part No. ______	
7	☐ Drive End Bearing Loading: ______ kPa	
8	▷ Special Seals for Gas Purge (2.4.7.3) ______	
9	○ Provide Motor Preliminary Parameters With Proposal (6.2.2.3), State Per Unit Values, Motor: ______ kVA Base at Rated Voltage and 25^{0}C	
10	☐ X_{dv}" Rated Voltage (Saturated) Subtransient Reactance ______	
11	☐ X_{2v} Rated Voltage (Saturated) Negative-Sequence Reactance ______	
12	☐ T_{a3} Rated Voltage (Saturated) Armature Time Constant ______ Sec.	
13	☐ Rated MVA ______ ☐ Rated Terminal Voltage ______ kV	
14	▽ **Motor Parameters (State Per Unit Values, Motor ______ kVA Base at Rated Voltage and 25^{O}C):**	
15	X_l Armature Leakage Reactance ______	
16	X_{ad} Direct Axis Armature Reactance ______	
17	X_d Direct Axis Synchronous Reactance (Saturated) ______ Un-Saturated ______	
18	X_p Potier Reactance ______	
19	X'_d Direct Axis Transient Reactance (Saturated) ______ Un-Saturated ______	
20	X''_d Direct Axis Subtransient Reactance (Saturated) ______ Un-Saturated ______	
21	X_{aq} Quadrature Axis Armature Reactance ______	
22	X_q Quadrature Axis Synchronous Reactance (Saturated) ______ Un-Saturated ______	
23	X_f Field Leakage Reactance ______	
24	X'_q Quadrature Axis Transient Reactance (Saturated) ______ Un-Saturated ______	
25	X''_q Quadrature Axis Subtransient Reactance (Saturated) ______ Un-Saturated ______	
26	X_{kq} Quadrature Axis Amortisseur Reactance (Slip = 1.0) ______	
27	X_{kd} Direct Axis Amortisseur Reactance (Slip = 1.0) ______	
28	X_2 Negative Sequence Reactance (Saturated) ______ Un-Saturated ______	
29	R_a Stator Armature Resistance/Phase ______	
30	R_f Field Resistance (Without FDRs) ______	
31	R_{fr} Field Resistance (With FDRs) ______	
32	R_{kq} Quadrature Axis Amortisseur Resistance (Slip = 1.0) ______	
33	R_{kd} Direct Axis Amortisseur Resistance (Slip = 1.0) ______	
34	R_1 Positive Sequence Resistance ______	
35	R_2 Negative Sequence Resistance ______	
36	T_a Armature Short-Circuit Time Constant, Sec ______	
37	T'_{do} Direct Axis Transient Open-Circuit Time Constant, Sec ______	
38	T'_{qo} Quadrature Axis Transient Open-Circuit Time Constant, Sec ______	
39	T''_{do} Direct Axis Subtransient Open-Circuit Time Constant, Sec ______	
40	T''_{qo} Quadrature Axis Subtransient Open-Circuit Time Constant, Sec ______	
41	T'_d Direct Axis Transient Short-Circuit Time Constant, Sec ______	
42	T''_d Direct Axis Subtransient Short-Circuit Time Constant, Sec ______	
43	P_r Synchronizing Torque Coefficient, kW/Radian (For reciprocating loads only) ______	
44	C_w Winding Capacitance to Ground, Microfarads/Phase ______	
45	I_2^2t Limit ______	

SYNCHRONOUS MOTOR
API 546 3RD Edition -- DATA SHEETS
METRIC UNITS

JOB NO. ____ ITEM / TAG NO. ____
PURCHASE ORDER NO. ____
REQ. / SPEC. NO. ____
REVISION NO. ____ DATE ____ BY ____
PAGE 9 OF 11

1 **STATOR AND ROTOR WINDING REPAIR DATA** Rev

2 NOTE: **(Alpha key code)** ❍ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 ▽ **Stator Coil Information:**

5 Total Copper Weight ____ kg Copper Strand Size ____ Insulation ____

6 Number of Strands per Coil Turn ____ Turn Insulation Description ____

7 Number of Turns per Coil ____ Coil Ground-Wall Insulation Description ____

8 Coil Configuration ____ Rows by ____ Columns

9 Finished Coil Dimension in Slot Region, W x H x L (Also Give Tolerances): ____

10 Total Number of Stator Slots ____ Winding Throw ____ Winding Connection ____

11 Slot Filler Description - Thickness: Top ____ Side ____ Between Top-Bottom Coils ____

12 Stator Bore Diameter ____ Slot Dimensions ____ Stress Grading if Applicable ____

13 Special End-Turn Bracing ____

14 Coil Dimensional Drawing No. ____ Thickness Groundwall Insulation ____ mm

15 Thickness Turn Insulation ____ mm Thickness Strand Insulation ____ mm

16 Other: ____

17 ▽ **Rotor Winding Information:**

18 Total Copper Weight ____ kg Strand or Bar Size ____ Conductor Material ____

19 Insulation Description ____

20 General Description of Winding (Number of Turns, Formed Coil, size, Etc,) ____

21 ____

22 Damper Winding Description, If Applicable ____

23 ____

24 Retaining Ring Alloy, If Applicable ____

25 Ring Material ____ Ring Dimensions Premachining ____

26 Shaft Material ____

27 Other: ____

28 ____

29 **MISCELLANEOUS**

30 ____
31 ____
32 ____
33 ____
34 ____
35 ____
36 ____
37 ____
38 ____
39 ____
40 ____
41 ____
42 ____
43 ____
44 ____
45 ____

API	SYNCHRONOUS MOTOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ____ DATE ____ BY ____ PAGE **10** OF **11**

1	**ANALYSIS, SHOP INSPECTION, AND TESTS**				Rev
2	NOTE: **(Alpha key code)**	○ TO BE COMPLETED BY PURCHASER **(m or l)**	□ BY MANUFACTURER WITH PROPOSAL **(o or n)**	▽ BY MANUFACTURER AFTER ORDER **(s or q)**	▷ BY MANUFACTURER OR PURCHASER **(w or u)**
3	**Bold Type Indicates Typical Selection**				
4	**Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The**				
5	**Purchaser In the Notes Section Below.**				
6		**Required**	**Witnessed**	**Observed**	
7	**Acceptance Criteria (2.1.13; 6.7.2, a):**	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**	
8	**Coordination Meeting (6.3)**	●			
9	Design Review (6.5)	○			
10	Torsional Analysis (2.4.6.2.7) By ________	○			
11	Lateral Critical Speed Analysis (2.4.6.2.1)	○			
12	Review of Quality Control Program (4.2.3.4)	○			
13	Submit Test Procedures 6 Weeks Before Tests (4.3.1.5)	○			
14	Inspection for Cleanliness per API 614 (4.2.3.2; 4.2.3.3)	○	○	○	
15	Observance of Assembly/Dismantling (4.3.1.1)	○	○	○	
16	Demonstrate Accuracy of Test Equipment (4.3.1.16)	○	○	○	
17	Stator Core Test (4.3.4.1)	○	○	○	
18	Surge Comparison Test (4.3.4.2)	○	○	○	
19	Special Surge Test of Coils (4.3.4.2.1)	○	○	○	
20	Sacrifical Coils Cut Into Segments (4.3.4.2.1, c)	○	○	○	
21	Number of Segments Cut Each Coil __ Cuts in: Straight Section __ Bends __				
22	Partial Discharge Test (4.3.4.6)	○	○	○	
23	Balance in Minimum of 3 Planes (2.4.6.3.1)	○	○	○	
24	**Dynamic Balance Rotors 600 rpm and Above (2.4.6.3.1)**	●	○	○	
25	Final Balance (4.3.1.6.1)	○	○	○	
26	Component Balance for > 4 Pole (2.4.6.3.1)	○	○		
27	Residual Unbalance Verification Test (2.4.6.3.6)	○	○	○	
28	Balance Check with Half Coupling (2.4.6.3.3)	○	○	○	
29	Running Tests with Coupling Half (2.4.6.3.3; 4.3.1.6)	○			
30	Stator Inspection Prior to VPI (4.3.4.5)	○	○	○	
31	Sealed Winding Conformance Test (4.3.4.4)	○	○	○	
32	Power Factor Tip-Up Test (4.3.4.3)	○	○	○	
33	**Routine Test (4.3.2)**	●	○	○	
34	Insulation Resistance Using Table 7 (4.3.2.1, d)	○	○	○	
35	Bearing Dimensional & Alignment Checks Before Tests (4.3.2.1, j)	○	○	○	
36	Bearing Dimensional & Alignment Checks After Tests (4.3.2.1, k)	○	○	○	
37	Vibration Monitoring and Recording (4.3.3.6; 4.3.3.8)	○	○	○	
38	Complete Test (4.3.5.1.1)	○	○	○	
39	Efficiency (4.3.5.1.1, a)				
40	Locked Rotor (4.3.5.1.1, b)				
41	Open/Short-Circuit Saturation (4.3.5.1.1, c)				
42	Heat Run (4.3.5.1.1, d)				
43	Exciter Heat Run (4.3.5.1.1, e)				
44	No Load V-Curve (4.3.5.1.1, f)				
45	Sound Pressure Level Test (4.3.5.1.1, g)				

SYNCHRONOUS MOTOR
API 546 3RD Edition -- DATA SHEETS
METRIC UNITS

JOB NO. ________ ITEM / TAG NO. ________
PURCHASE ORDER NO. ________
REQ. / SPEC. NO. ________
REVISION NO. ________ DATE ________ BY ________
PAGE 11 OF 11

ANALYSIS, SHOP INSPECTION, AND TESTS (CONTINUED)

Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The Purchaser In the Notes Section Below.

	Required	**Witnessed**	**Observed**
Acceptance Criteria (2.1.13; 6.7.2, a):	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**
DC High-Potential Test (4.3.5.1.2)	○	○	○
Torque Pulsations During Starting	○	○	○
Rated Rotor Temperature-Vibration Test (4.3.5.2.1)*	○	○	○
*(For Motors Not Receiving Complete Test)			
Unbalance Response (4.3.5.3)	○	○	○
Bearing Housing Natural Frequency Test (4.3.5.4)	○	○	○
Certification of Materials (4.2.1.1, a)	○	○	○
Final Assembly Running Clearances (4.2.1.1, e)	○	○	○
Material Inspection (4.2.2)	○	○	○
Radiographic Test (4.2.2.2) Parts ________	○	○	○
Ultrasonic Test (4.2.2.3) Parts ________	○	○	○
Ultrasonic inspection of shaft forging (2.4.5.1.8)	○	○	○
Magnetic Particle Test (4.2.2.4) Parts ________	○	○	○
Liquid Penetrant Test (4.2.2.5) Parts ________	○	○	○
Certified Data Prior to Shipment (4.3.1.15; 6.7.2, a)	○	○	○
Burn-in Testing of Rotating Element Mounted Electronic Components (2.5.3.3)	○	○	○
Heat Exchanger Performance Verification Test (TEWAC Enclosures) (4.3.5.5)	○	○	○
Pulsating Torque Tests for 4 & 6 Pole Machines (4.3.5.1.3)	○	○	○
Other: ________	○	○	○
________	○	○	○

NOTES

Annex B

Synchronous Generator Data Sheets

This annex comprises data sheets for generators purchased to API 546, third edition. There are two sets of sheets, one for US Standard Units, and one for Metric Units.

SYNCHRONOUS GENERATOR
API 546 3RD Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS

JOB NO. ______ ITEM / TAG NO. ______
PURCHASE ORDER NO. ______
REQ. / SPEC. NO. ______
REVISION NO. ______ DATE ______ BY ______
PAGE 1 OF 11

FOR / USER ______ DRIVEN EQUIPMENT ______ Rev

SITE / LOCATION ______ QUANTITY ______

SUPPLIER ______ ▽ SUPPLIER PROJECT NO. ______

ITEM NAME ______

Applicable To: ❍ Proposal ❍ Purchase ❍ As Built

GENERAL

NOTE: **(Alpha key code)** ❍ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Basic Data:

Applicable Standards (1.3.1; 1.3.2; 1.6): ❍ **North American (i.e., ANSI, NEMA)** ❍ International (i.e., IEC, ISO)

Nameplate Power (2.2.1.1): ______ kW ______ RPM (Synchronous)

______ Volts (2.2.1.2) ______ Phase ______ Hertz Duty: ❍ Continuous ❍ Other ______

Rated PF: ______ Insulation Class: ______ Voltage and Frequency Variations (2.2.1.2.1) ______

Stator Temperature Rise (2.3.1.1) ______ °C Above ______ °C By RTD

Rotor Temperature Rise ______ °C Above ______ °C By Resistance ❍ Sealed Exciter Windings Required (2.3.1.6)

☐ Manufacturer's Type ______ ☐ Frame Size ______

Other: ______

Site Data (2.1.2):

Area Classification (2.1.8): ❍ Nonclassified ❍ Classified as: Class ______ Group ______ Division ______ Autoignition Temp ______ °C

Class ______ Group ______ Zone ______

Maximum Sound Pressure Level (2.1.3): ❍ **85 dBA @ 3 ft. NO-LOAD, FULL VOLTAGE/FREQUENCY, SINE WAVE POWER** ❍ ______ dBA

Ambient Temperature: Max ______ °F Min ______ °F

Relative Humidity: Max ______ % Min ______ %

Generator Location: ❍ Indoor ❍ Outdoor Roof Over Generator: ❍ Yes ❍ No

Building Temperature Controlled: ❍ Yes ❍ No Site Elevation: ______ ft.

Nonmassive Foundation (2.4.6.1.2), Description ______

Unusual Conditions:

Dust (2.4.1.2.2,c) ______ Chemicals (2.1.2) ______

Seismic Loading (2.4.2.2) ______ Corrosive Agents (2.4.10.1.2) ______

Other: ______

Enclosure (2.4.1.2.1):

❍ Weather Protected (WP) (2.4.1.2.2) ❍ Type 1 ❍ Type II

Air Filters: ❍ Provision Only (3.5.2) ❍ Required (3.5.4) ❍ **90%, 10 µm** ❍ Other ______

▷ Manufacturer ______ ▷ Type ______ ▷ Model ______

Differential Pressure Switch (3.5.5): ❍ Provision Only ❍ Required ❍ Differential Pressure Guage (3.5.5)

▷ Manufacturer ______ ▷ Type ______ ▷ Model ______

❍ Explosion Proof ❍ TEFC (2.4.1.2.3) ❍ Drip Proof Guarded ❍ TEPV (2.4.1.2.3) ❍ Other ______

❍ TEAAC (2.4.1.2.3) Tube Materials (2.4.10.8,a): ❍ Copper ❍ Copper Alloy

❍ Aluminum Alloy ❍ Stainless Steel ❍ Other ______

Notes: ______

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 2 OF 11

GENERAL (CONTINUED) Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Enclosure (2.4.1.2.1) (Continued):

○ TEWAC (2.4.1.2.4) Tube Materials (2.4.10.8, b): ○ **Cu-Ni** ○ Other ______

Redundant Coolers (2.4.1.2.4, b): ○ Yes ○ No Exchanger Location/Orientation (2.4.1.2.4, c) ______

Cooling Water Conditions per 2.4.1.2.4, a: ○ Yes ○ No (Other) ______

□ Water Flow (GPM) Max ______ Min ______ □ Water Pressure (PSI) Max ______ Min ______

Tube Construction (2.4.1.2.4, d; 2.4.10.8, c): ○ **Single Tube** ○ Double Tube

○ Flow Sensor Local Indicator Required (2.4.1.2.4, g) Relay Contacts: ○ NO ○ NC

○ Air Temperature Sensor Required (2.4.1.2.4, h), Type ______

○ Leak Detection Required ○ **Inner** ○ Outer ▷ Type and Description ______

▽ High Flow Alarm Set Point ______ GPM ▽ Low Flow Shutdown Set Point ______ GPM

○ Provision for Pre-Start Purging (2.4.1.1, e) ______ ○ Marine Garde Stainless Steel Fasteners (2.4.1.1, c)

○ Degree of Protection IP (2.4.1.2.1) IP ______ ○ Method of Cooling IC (2.4.1.2.1) IC ______

Other: ______

Mounting:

○ Horizontal: ○ Foot Mounted ○ Flange Mounted ▷ Flange Details ______

○ Vertical: ○ Shaft Up ○ Shaft Down

○ Pedestal ○ Axial Stator Shift Required (2.4.2.15)

○ Engine Type Bearings Furnished By ______ Shaft Furnished By ______

○ Baseplate: Furnished By (2.4.2.6): ______ ○ Soleplate: Furnished By (2.4.2.6): ______

○ Special Connections for Field Piping (2.4.3.1): ______

▽ When Rotor Dynamic Analysis Is Specified, List of Foundation Data Required From Purchaser (2.4.6.1.2): ______

______

______

Electrical System:

Primary Power Source ______ Volts ______ Phase ______ Hertz Maximum Ground Fault ______ Amps

Method of System Grounding (3.6.2.3) ○ Resistance ○ Reactance ○ Ungrounded ○ Solid

Fault Current at Machine Terminals (3.1.2) ______ MVA Let-Through Energy (3.1.2): ______ I^2t (Ampere-squared seconds)

○ Parallel Operation Requirements with Existing Equipment, Define: ______

______

Other: ______

Bearings:

Bearing Type: ○ **Hydrodynamic (2.4.7.1.1)** ○ Split Sleeve (2.4.7.1.2) ○ Tilting Pad (2.4.7.1.2) ○ Oil Ring Required (2.4.8.1)

○ Antifriction (2.4.7.1.3)

○ Thrust Bearing (2.4.7.1.5) Max Driver Thrust Downthrust Momentary ______ lb. Upthrust Momentary ______ lb.

Continuous ______ lb. Continuous ______ lb.

○ Bearing Constant-Level Sight Feed Oilers Required (2.4.7.2.2) Type: ______

○ Special Seals for Gas Purge (2.4.7.3, a) ○ Non-conducting Seals (2.4.7.3, b)

Notes: ______

______

______

______

______

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ________ ITEM / TAG NO. ________ PURCHASE ORDER NO. ________ REQ. / SPEC. NO. ________ REVISION NO. ________ DATE ________ BY ________ PAGE 3 OF 11

Rev

LUBRICATION SYSTEM

NOTE: (Alpha key code) TO BE COMPLETED BY PURCHASER **(m or l)** BY MANUFACTURER WITH PROPOSAL **(o or n)** BY MANUFACTURER AFTER ORDER **(s or q)** BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

SELF-LUBE (2.4.8.1) Pressurized Lube Required (2.4.8.1) System Supplied By (2.4.8.4): ________ Common With Driver

Per API 614: ________ -purpose oil system (2.4.8.6) Main Oil Pump Required: Integral Shaft Driven Separate

Oil Rings Not Provided

Type/Viscosity of Oil (2.4.8.8) ________ Pressure (2.4.8.4; 2.4.8.5) ________ PSIG

Total Bearing Oil Requirements (6.2.3): ________ GPM ________ PSI Heat Loss To Be Removed ________ kW

Antifriction Bearings: Grease: Type ________ Oil Mist (2.4.7.4.1) Pure mist Purge mist

Other: ________

SPECIAL CONDITIONS

Shaft and Spider one piece forging for 4 or more poles (2.4.5.1.2, b; 2.4.5.1.4)

Special Vibration Requirements (4.3.3.10) ________

Efficiency Evaluation Factor (EF) (6.2.1) ________ (value) ________ (currency) /kW applied at ________ % of F.L.

National, State / Provincial, or Local Codes (2.1.8): ________

External Forces on Generator Housing That May Affect Site Performance (2.1.13; 2.4.4): ________

Special Overspeed Requirement (2.4.5.2.7): ________

Other: ________

MAIN CONDUIT BOX

Main Terminal Box (3.1.1):

Box Location ________ Conductor Size ________ Type ________ Insulation ________ Qty. Per Phase ________

Quick Disconnect Type Bushing Studs or Receptacles (3.1.6, f) ________

Space for Termination of Shielded Cables (3.1.6, e) Cable Entering From (3.1.4): Top Bottom Drive Side Non-Drive End Side

Both Ends of Stator Winding Brought Out To Terminal Box (2.2.2.2) Thermal Insulation (3.1.6, a)

Cable Between Stator Windings and Main Terminals (2.3.1.11): Yes No Description: ________

Space Heaters (3.1.6, b): Temp. Code ________ ________ Volts ________ Phase ________ Hz ________ kW

Differential Protection Current Transformers (2.2.2.2; 3.1.6, h; 3.1.8; 3.6.3): Accuracy Class ________ Ratio ________ Quantity ________

Type: Self-balancing Full Differential Supplied By ________ Mounted By ________

Surge Capacitors (3.1.6, g; 3.6.2.1): Microfarads ________ Supplied By ________ Mounted By ________

Surge Arresters (3.1.6, g; 3.6.2.2): kV Rated ________ Supplied By ________ Mounted By ________

Current Transformers (3.1.6, h) for Ammeter Accuracy Class ________ Ratio ________ Quantity ________

Supplied By ________ Mounted By ________

Potential Transformers (3.1.6, j) for Voltmeter Accuracy Class ________ Ratio ________ Quantity ________

Fuses Required Supplied By ________ Mounted By ________

Provision for Purging (3.1.6, c)

Removable Links (3.1.6, d) Silver- or Tin- Plated Bus Joints (3.1.6, i) Ground Bus (3.1.6, k)

Insulated Terminations and Interior Jumpers (3.1.6, m)

Notes: ________

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 4 OF 11

1 **ACCESSORIES** Rev

2 NOTE: **(Alpha key code)** ❍ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 ❍ **Frame Space Heaters (3.4):** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase ☐ ____ kW

5 ❍ **Bearing Heaters (2.4.8.3):** Temp. Code ____ Type ____ ____ Volts ____ Phase ☐ ____ kW

6 ❍ **Exciter Space Heaters:** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase ☐ ____ kW

7 **Winding Temperature Detectors (3.2.1):** ❍ **Three Per Phase, 3 Wire Platinum, 100 Ohms at 32°F** ❍ Ground One Common Lead (3.2.1.2)

8 ❍ Other Detector: Qty / Phase ____ Type ____ Material ____ Wires ____

9 ❍ Thermocouples: Qty / Phase ____ Type ____

10 ▽ Recommended Settings: Alarm ____ °F Shutdown ____ °F

11 **Monitors and Devices** ❍ Monitor for Shaft Grounding Brush Replacement (2.4.7.1.9)

12 ❍ Test Device For Rotating Electronic Components (2.5.3.8) ❍ Rotating Diode Failure Detection (2.5.3.12)

13 ❍ Online Rotor Monitoring System (2.5.3.10): Description: ____

14 **Exciter Power Supply** ❍ Permanent Magnet Generator (2.5.3.13) ❍ Constant Voltage Transformer (2.5.1.5) ❍ Phase Controlled Rectifier (2.5.1.5)

15 ❍ Other (2.5.1.5) ____

16 **Auxiliary Equipment Enclosures (3.1.4):** ❍ Box Location (Facing Opposite Drive End) ____

17 Conduit/Cable Entry From: ❍ Bottom ❍ Other: ____

18 **Hydrodynamic & Thrust Bearing Temperature Devices (3.3):**

19 ❍ Provision Only ❍ Install per API 670 (3.3.1) ❍ Other ____

20 ❍ **RTD's (3.3.1)** Qty / Brg. ____ Type ____ Material ____ Wires ____ ❍ Ground One Common Lead (3.2.1.2)

21 ❍ Thermocouple: Qty / Brg. ____ Type ____ Material ____ Wires ____

22 ❍ Dial Type Thermometers (2.4.7.1.16): Type ____ ❍ Alarm Contacts Number of Contacts ____ ❍ NO ❍ NC

23 Location of Bearing Temperature Sensor Wire Terminations: ▷ Terminal box at generator side ▷ In the Stator RTD T Box ▷ Conduit Head at Bearing

24 ▽ Bearing Temperature Recommended Settings: Alarm ____ °F Shutdown ____ °F

25 ▽ Thrust Bearing Temp. Recommended Settings: Alarm ____ °F Shutdown ____ °F

26 **Vibration Detectors (3.8):** **Generators 1200 rpm and higher** Installed Qty / Bearing: ❍ **TWO (3.8.1)** ❍ Four (3.8.2)

27 Phase Reference Probe (3.8.1): ❍ Provisions Only ❍ **INSTALLED**

28 **Generators less than 1200 rpm** Installed Qty / Bearing: ❍ Two (3.8.1) ❍ Four (3.8.2)

29 Phase Reference Probe (3.8.1): ❍ Provisions Only ❍ Installed

30 Vibration Probe Leads Protected by (3.8.1.1; 3.9.1; 3.9.2): ❍ Liquidtight Flexible Metal Conduit, Length ____ ft.

31 ❍ Other Description: ____

32 ▷ Probe, Oscillator-Demodulator Mfr. ____ Model / Series ____

33 ▷ Probe Supplied By ____ Installed by ____ ▷ Osc.-Demod. Furnished By ____ Installed by ____

34 Bearing Housing Seismic Sensors (3.8.3) ❍ Provisions Only ❍ Installed Sensor Type ____ Sensor Mfr. ____

35 Qty / D.E. Bearing ____ Location (H, V, A) ____ Qty / N.D.E. Bearing ____ Location (H, V, A) ____

36 ▷ Sensor Supplied By ____ Installed by ____ ▷ Transducer Furnished By ____ Installed by ____

37 Location of Vibration Sensor Wire Terminations: ▷ Terminal box at generator side ▷ Within Sensor Housing ▷ Other ____

38 Vibration Switch: ❍ Manual Reset ❍ Electric Reset Switch Type: ____ Model: ____

39 Terminal Head or Box (3.1.11) ____

40 **Alarm and Control Switches (3.6.1): SPDT 10 Amp 115 Volt** ❍ DC Rated Contacts: ____ ❍ **AC Rated Contacts:** ____

41 **Partial Discharge Detectors (3.6.4; 3.1.6, l)** ❍ Yes Describe Required System: ____

42 ____

43 **Separately Powered Auxiliary Fan(s) (2.4.10.6.3): Driver Information (where applicable)** ▷ Standard No. ____

44 Quantity ____ Location ____ Encl. ____ HP ____ RPM ____ ____ Volts ____ Phase ____ Hertz

45 Quantity ____ Location ____ Encl. ____ HP ____ RPM ____ ____ Volts ____ Phase ____ Hertz

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE **5** OF **11**

CONTROLS Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

▽ IEEE Type ______ Excitation System, See IEEE 421.1

▽ Excitation System Voltage Response Ratio (Over A 0.5 Second Interval), Using the IEEE 421.1 Definition ______

______

▽ Excitation System Voltage Response Time, Per IEEE 421.1, Sec ______

▽ Exciter Ceiling Voltage, When Loaded by the Main Generator Rotor Field Resistance (at 212°F) ______ V DC

Generator Vendor to Furnish:

○ Synchronous Machine Regulator (Voltage Regulator) Mfr. ______ Model ______

Excitation System:

○ Permanent Magnet Generator Excitation Source

○ High Initial Response Excitation System Required

▽ Short circuit currents vs. time for three phase fault conditions, line to line and line to ground fault conditions (6.2.2.2, a).

Curve No. ______

▽ Transient (momentary) voltage regulation (6.2.2.2, b) during sudden application and removal of specified load:

Load kV ______ kvar ______ OVReg ______

▽ Total and single harmonic voltages expressed in percent of fundamental voltage for line to line and line to neutral (6.2.2.2, c) while unit operating at rated voltage, frequency and no load. ______

○ Power System Stabilizer Required (Applied to the Synchronous Machine Regulator) ______

Other: ______

○ Manufacturer's Standard Excitation Control (Includinng Application & Protection) Package

Mount Excitation Control Package in: ○ Purchaser's Switchgear ○ Vendor Furnished Panel

○ Separate Control Devices, as Checked, for Mounting in: ○ Purchaser's Switchgear ○ Vendor Furnished Panel

○ Completely Assembled Control Panel with Devices as Checked (3.6.5.2)

Devices Mounted on Front of Panel, Labeled as Indicated:

○ Frequency ______ Hz Scale

○ Ammeter (0 - 5 A), 0 - ______ A Scale

○ Voltmeter (0 - 150 VAC), 0 - ______ kV Scale, "GENERATOR VOLTAGE"

○ "POWER FACTOR" Meter, 0.80 - 1 - 0.80 Scale or ______ - ______ - ______ Scale

○ Ammeter, 0 - ______ Amps Scale, "EXCITER FIELD AMPERES"

○ Potentiometer, "EXCITER FIELD" ○ "EXCITER FIELD ON-OFF" Test Switch

○ Generator Field-Ground Relay, "MAIN FIELD GROUND" Type ______

○ Overcurrent Relays (3), Instantaneous, 0.5 - 2 A Range, Manufacturer ______ Catalog No. ______

○ Overtemperature Relay, 122 - 374°F Range, For Use with ______ Ohm RTD, "STATOR TEMPERATURE"

Manufacturer ______ Catalog No. ______

Quantity ______ Type ______

○ Alarm Panel ○ Automatic Power-Factor Controller (2.5.1.4) ○ VAR Controller (2.5.1.4)

○ Vibration Probe Monitors: Manufacturer ______ Model ______

○ Temperature Indicator, ______ °F

○ Synchronoscope, With Lights ○ Synchronism-Check Relay, Type ______

○ Automatic Synchronizer, Type ______

______

Other: ______

______

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 6 OF 11

CONTROLS (CONTINUED)

Rev

NOTE: (Alpha key code) ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Devices Mounted on Front of Panel, Labeled as Indicated (Continued):

○ Automatic Voltage Regulator (Synchronous Machine Regulator)

○ Single ○ Dual with Null Adjustment ○ Dual with Automatic Matching Feature

○ Volts/Hertz Limiter

○ Other ______

Devices Mounted Inside Panel, Labeled to Coincide with Drawing Identification:

○ Control Power Transformer, Constant Voltage, ______ kVA, ______ V - 120 V Rated to Maintain 95 % Secondary Voltage with 50% Sag of Primary Voltage ○ Phase Controlled Rectifier (2.5.1.5)

○ Full-Wave Bridge, Silicon Rectifiers ______ A (Min of 125 % of Exciter Field Amperes), Convection Cooled

○ Contactor Exciter Field Current

○ Field Monitor Relay, to Switch and Signal on Loss of Field or Out of Step Condition

○ Auxiliary and Timing Relays, as Required ○ Surge Suppressors and Fuses, as Required

○ Terminal Blocks, Heavy Duty, Identified by Unique Numbers, Number as required with 20 % Spares ______

○ Switches required for Alarm and Control devices (3.6.1): Contacts: **AC** ______ DC ______

○ Control Panel Wiring Entrance: ○ Top ○ Bottom ○ Side

○ Other: ______

DRIVER EQUIPMENT INFORMATION

Prime Mover Equipment: Tag No. ______ Description ______ Location

▷ Furnish Performance Curves, Curve Numbers (6.2.2) ______

Driver Equipment Mfr. ______ Type / Model No. ______ RPM ______

Driver Connection to Load: ○ Direct Coupled ○ Through Gearbox

Speed-Increasing-Reducing Gear (2.2.3.2, c): Ratio ______ Gear WK^2 (2.2.3.2,c) ______ lb-ft^2 at ______ rpm

Total Driver-Equipment WK^2 (2.2.3.2, c) ______ lb-ft^2 at ______ RPM

Generator Shaft Extension (2.4.5.1.9): ○ Cylindrical Fit ○ Taper Fit ○ Flange ○ Other Coupling data ______

Rotation ***Viewed from Opposite Drive End of Generator:*** ▷ Clockwise ▷ Counterclockwise

Coupling (2.4.9.4): Type ______ Mfr. ______ Type / Model ______

▷ Manufacturer's Standard ▷ Per API 671

Coupling WK^2 (2.2.3.2, c) ______ lb-ft^2 at ______ rpm Mass Moment of Coupling Half (2.4.6.2.2, f): ______ lb-ft^2

Supplied By: ○ Generator Mfr. ○ Driver Equipment Mfr ○ Purchaser ○ Others ______

Mounted By: ○ Generator Mfr. ○ Driver Equipment Mfr ○ Purchaser ○ Others ______

Other: ______

MISCELLANEOUS

○ Manufacturer's Standard Paint ○ Extra Coat at Shipment ○ User's Special Paint ______ ○ Outline for Special Weather Protection (6.2.14)

○ Proof of Nonsparking, Corrosion-Resistant Fan (2.4.10.6.1): ○ Quantity of Special Tools and Lifting Required (2.1.12; 2.4.2.13): ______

▷ Special Low-Temp Material Requirements (2.4.10.4) ______

▷ Special Winterizing Requirements (6.2.14) ______

○ Materials To Be Identified With ANSI, ASTM, or ASME Numbers (6.2.17) ______

○ Typical Drawings & Literature with Proposal ○ Electronic Instruction Manuals (6.6.1) Qty: ___ ○ Photos showing assembly steps required (6.8.5)

○ Performance Curves Supplied in Digitial Format (6.6.1) Digitial Format Description: ______

○ Manufacturer To Supply Curve Data in Tabular Format (6.6.1) ○ NRTL Certification (6.8.6) Qty: ___ ○ PMI Certification (6.8.6) Qty: ___

○ Detailed instructions and photographs for disassembly and inspection (6.8.4, c) Qty: ___ ○ Certified Drawings (6.6.2) Qty: ___

Other: ______

	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 7 OF 11

Rev

MISCELLANEOUS CONTINUED

NOTE: **(Alpha key code)** ❍ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection Nameplate Material (2.4.11.1): ❍ **Stainless Steel** ❍ Other ______

❍ Type Tests and Design Information Verifying All Gasket Materials are Impervious to Lube Oil and Chemicals (3.1.4), Qty of Type Tests Documentation ____

❍ Special Identification for Transmittals (6.4.2, e) ❍ Separate Nameplate with Purchaser's Information (2.4.11.4)

______ ______

______ ______

Shipment (4.4.1): ❍ Domestic ❍ Export ❍ Export Boxing Required ❍ Commissioning Assistance Required (6.2.16) ❍ Mounted on Skid(4.4.1, e)

❍ Special Shipping Bearings (4.4.1, k) ❍ Outdoor Storage for More Than Six Months (4.4.1) ❍ Piping Assembled (4.4.1, h)

❍ Electronic Vibration Test Data (4.3.3.15) Digital Format Description: ______ Qty: ____

❍ Provide Separate Price For Each Optional Test (6.2.13)

Other: ______

GENERATOR DATA - FIRST SECTION

☐ Manufacturer ______ ☐ Type / Model No. ______ ☐ Frame Size / Designation ______

Qty. ____ ______ kW ______ RPM (Syn.) ______ Poles ______ Volts ______ Phase ______ Hz

Insulation Class ______ Temperature Rise Class CLASS B Enclosure ______

Rated Speed ______ RPM Rotor WK^2 (6.2.2.2, d) ______ $lb\text{-}ft^2$

☐ **Calculated Expected Data (6.2.2.2, f) at the following Loads:**

Load Point	50%	75%	100%	❍ Other: ____ %
Efficiency	____ %	____ %	____ %	____ %
Power Factor	____ %	____ %	____ %	____ %
Current	____ Amps	____ Amps	____ Amps	____ Amps

❍ Guaranteed Efficiencies (6.2.2.2, g) at the following Loads: ▷ Test Method (6.2.2.2, f): ______

Load Point	25%	50%	75%	100 %	❍ Other: ____ %
Efficiency	____ %	____ %	____ %	____ %	____ %
Power Factor	____ %	____ %	____ %	____ %	____ %
Current	____ Amps	____ Amps	____ Amps	____ Amps	____ Amps

☐ Short Circuit Currents vs. Time (6.2.2.2, a) Curve No. ______

☐ Transient Voltage Regulation (6.2.2.2, b) at:

100% Load Addition and Load Removal: ______

▷ Other: ____ % Load Addition and Load Removal: ______

☐ Synchronizing Power (6.2.2.2, h) at No Load ______ Pr ☐ Synchronizing Power (6.2.2.2, h) at Full Load ______ Pr

☐ Rated Generator Field: ____ Amps ____ Volts ☐ Reactive Capability Curve No. ______

☐ Rated Exciter Field: ____ Amps ____ Volts ❍ Calculated Rotor-Response (6.7.2, b) ☐ Curve Nos. (6.7.2, b): ______

☐ Max. Sound Pressure Level (2.1.3) ____ dBA @ 3 ft., no-load

☐ Weights: Net: ______ lb. Stator ______ lb. Rotor ______ lb. Shipping ______ lb.

Rotor Construction: ☐ Solid Cylindrical ☐ Laminated Cylindrical ☐ Salient-Pole Solid

☐ Salient-Pole "Start" Punching Type, Shrunk Onto Shaft ☐ Salient-Pole Laminated/Bolted

☐ Salient-Pole Dove-Tail or T-Tail Attachment to Shaft ☐ Other ______

☐ Minimum % Overspeed (2.1.5; 2.4.5.2.7) ______

Other: ______

______

______

______

______

API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 8 OF 11

1 **GENERATOR DATA - SECOND SECTION** Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 **Bearings:**

5 Bearing Type Required: ▷ Hydrodynamic (2.4.7.1.1) ▷ Oil Rings Required (2.4.8.1) ▷ Antifriction (2.4.7.1.3)

6 Thrust Bearings, Maximum Connected Equipment Thrust (2.4.7.1.11) ____

7 Bearing, Drive End: Capable of Self-Lube ____ Manufacturer ____ Type ____ Model / Part No. ____

8 Bore Diameter: Min ____ in. Max ____ in. Bore Length ____ in.

9 Design Clearance with Shaft: Min ____ in. Max ____ in. Bearing Loading: ____ PSI

10 Bearing, Non-Drive End: Capable of Self-Lube ____ Manufacturer ____ Type ____ Model / Part No. ____

11 Bore Diameter: Min ____ in. Max ____ in. Bore Length ____ in.

12 Design Clearance with Shaft: Min ____ in. Max ____ in. Bearing Loading: ____ PSI

13 Thrust Bearing: □ Non-Drive End Manufacturer ____ Type ____ Model / Part No. ____

14 □ Drive End Bearing Loading: ____ PSI

15 ▷ Special Seals for Gas Purge (2.4.7.3) ____

16 Other: ____

17 ○ Provide Generator Preliminary Parameters With Proposal (6.2.2.3), State Per Unit Values, Generator: ____ kVA Base at Rated Voltage and 77°F

18 □ X_{dv}'' Rated Voltage (Saturated) Subtransient Reactance ____

19 □ X_{2v} Rated Voltage (Saturated) Negative-Sequence Reactance ____

20 □ T_{a3} Rated Voltage (Saturated) Armature Time Constant ____ Sec.

21 □ Rated MVA ____ □ Rated Terminal Voltage ____ kV

22 ▽ **Generator Parameters (State Per Unit Values, Generator ____ kVA Base at Rated Voltage and 77°F):**

23 X_l Armature Leakage Reactance ____

24 X_{ad} Direct Axis Armature Reactance ____

25 X_d Direct Axis Synchronous Reactance (Saturated) ____ Un-Saturated ____

26 X_p Potier Reactance ____

27 X'_d Direct Axis Transient Reactance (Saturated) ____ Un-Saturated ____

28 X''_d Direct Axis Subtransient Reactance (Saturated) ____ Un-Saturated ____

29 X_{aq} Quadrature Axis Armature Reactance ____

30 X_q Quadrature Axis Synchronous Reactance (Saturated) ____ Un-Saturated ____

31 X_f Field Leakage Reactance ____

32 X'_q Quadrature Axis Transient Reactance (Saturated) ____ Un-Saturated ____

33 X''_q Quadrature Axis Subtransient Reactance (Saturated) ____ Un-Saturated ____

34 X_{kq} Quadrature Axis Amortisseur Reactance (Slip = 1.0) ____

35 X_{kd} Direct Axis Amortisseur Reactance (Slip = 1.0) ____

36 X_0 Zero Sequence Reactance (6.2.2.2, e) ____

37 X_2 Negative Sequence Reactance (Saturated) ____ Un-Saturated ____

38 R_a Stator Armature Resistance/Phase ____

39 R_f Field Resistance (Without FDRs) ____

40 R_{fr} Field Resistance (With FDRs) ____

41 R_{kq} Quadrature Axis Amortisseur Resistance (Slip = 1.0) ____

42 R_{kd} Direct Axis Amortisseur Resistance (Slip = 1.0) ____

43 R_0 Zero Sequence Resistance ____

44 R_1 Positive Sequence Resistance ____

45 R_2 Negative Sequence Resistance ____

SYNCHRONOUS GENERATOR
API 546 3RD Edition -- DATA SHEETS
U.S. CUSTOMARY UNITS

JOB NO. ______ ITEM / TAG NO. ______
PURCHASE ORDER NO. ______
REQ. / SPEC. NO. ______
REVISION NO. ______ DATE ______ BY ______
PAGE **9** OF **11**

GENERATOR DATA - SECOND SECTION CONTINUED Rev

NOTE: (Alpha key code) ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

T_a Armature Short-Circuit Time Constant, Sec ______

T'_{do} Direct Axis Transient Open-Circuit Time Constant, Sec ______

T'_{qo} Quadrature Axis Transient Open-Circuit Time Constant, Sec ______

T''_{do} Direct Axis Subtransient Open-Circuit Time Constant, Sec ______

T''_{qo} Quadrature Axis Subtransient Open-Circuit Time Constant, Sec ______

T'_d Direct Axis Transient Short-Circuit Time Constant, Sec ______

T''_d Direct Axis Subtransient Short-Circuit Time Constant, Sec ______

C_w Winding Capacitance to Ground, Microfarads/Phase ______

I_2^2t Limit ______

Other: ______

STATOR & ROTOR WINDING REPAIR DATA

▽ **Stator Coil Information:**

Total Copper Weight ______ lb. Copper Strand Size ______ Insulation ______

Number of Strands per Coil Turn ______ Turn Insulation Description ______

Number of Turns per Coil ______ Coil Ground-Wall Insulation Description ______

Coil Configuration ______ Rows by ______ Columns

Finished Coil Dimension in Slot Region, W x H x L (Also Give Tolerances): ______

Total Number of Stator Slots ______ Winding Throw ______ Winding Connection ______

Slot Filler Description - Thickness: Top ______ Side ______ Between Top-Bottom Coils ______

Stator Bore Diameter ______ Slot Dimensions ______ Stress Grading if Applicable ______

Special End-Turn Bracing ______

Coil Dimensional Drawing No. ______ Thickness Groundwall Insulation ______ mils

Thickness Turn Insulation ______ mils Thickness Strand Insulation ______ mils

Other: ______

▽ **Rotor Winding Information:**

Total Copper Weight ______ lb. Strand or Bar Size ______ Conductor Material ______

Insulation Description ______

General Description of Winding (Number of Turns, Formed Coil, size, Etc,) ______

Damper Winding Description, If Applicable ______

Retaining Ring Alloy, If Applicable ______

Ring Material ______ Ring Dimensions Premachining ______

Shaft Material ______

Other: ______

API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 10 OF 11	

1	**ANALYSIS, SHOP INSPECTION, AND TESTS**				Rev
2	NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**				
3	**Bold Type Indicates Typical Selection**				
4	**Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The**				
5	**Purchaser In the Notes Section Below.**				
6		**Required**	**Witnessed**	**Observed**	
7	**Acceptance Criteria (2.1.13; 6.7.2, a):**	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**	
8	**Coordination Meeting (6.3)**	●			
9	Design Review (6.5)	○			
10	Torsional Analysis (2.4.6.2.7) By ______	○			
11	Lateral Critical Speed Analysis (2.4.6.2.1)	○			
12	Review of Quality Control Program (4.2.3.4)	○			
13	Submit Test Procedures 6 Weeks Before Tests (4.3.1.5)	○			
14	Inspection for Cleanliness per API 614 (4.2.3.2; 4.2.3.3)	○	○	○	
15	Observance of Assembly/Dismantling (4.3.1.1)	○	○	○	
16	Demonstrate Accuracy of Test Equipment (4.3.1.16)	○	○	○	
17	Stator Core Test (4.3.4.1)	○	○	○	
18	Surge Comparison Test (4.3.4.2)	○	○	○	
19	Special Surge Test of Coils (4.3.4.2.1)	○	○	○	
20	Sacrifical Coils Cut Into Segments (4.3.4.2.1, c)	○	○	○	
21	Number of Segments Cut Each Coil ___ Cuts in: Straight Section ___ Bends ___				
22	Partial Discharge Test (4.3.4.6)	○	○	○	
23	Balance in Minimum of 3 Planes (2.4.6.3.1)	○	○	○	
24	**Dynamic Balance Rotors 600 rpm and Above (2.4.6.3.1)**	●	○	○	
25	Final Balance (4.3.1.6.1)	○	○	○	
26	Component Balance for > 4 Pole (2.4.6.3.1)	○	○		
27	Residual Unbalance Verification Test (2.4.6.3.6)	○	○	○	
28	Balance Check with Half Coupling (2.4.6.3.3)	○	○	○	
29	Running Tests with Coupling Half (2.4.6.3.3; 4.3.1.6)	○			
30	Stator Inspection Prior to VPI (4.3.4.5)	○	○	○	
31	Sealed Winding Conformance Test (4.3.4.4)	○	○	○	
32	Power Factor Tip-Up Test (4.3.4.3)	○	○	○	
33	**Routine Test (4.3.2)**	●	○	○	
34	Insulation Resistance Using Table 7 (4.3.2.1, d)	○	○	○	
35	Bearing Dimensional & Alignment Checks Before Tests (4.3.2.1, j)	○	○	○	
36	Bearing Dimensional & Alignment Checks After Tests (4.3.2.1, k)	○	○	○	
37	Vibration Monitoring and Recording (4.3.3.6; 4.3.3.8)	○	○	○	
38	Complete Test (4.3.5.1.1)	○	○	○	
39	Efficiency (4.3.5.1.1, a)				
40	Open/Short-Circuit Saturation (4.3.5.1.1, c)				
41	Heat Run (4.3.5.1.1, d)				
42	Exciter Heat Run (4.3.5.1.1, e)				
43	No Load V-Curve (4.3.5.1.1, f)				
44	Sound Pressure Level Test (4.3.5.1.1, g)				
45	Other: ______				

	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS U.S. CUSTOMARY UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 11 OF 11

ANALYSIS, SHOP INSPECTION, AND TESTS CONTINUED

Rev

NOTE: **(Alpha key code)** — ❍ TO BE COMPLETED BY PURCHASER **(m or l)** — ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** — ▽ BY MANUFACTURER AFTER ORDER **(s or q)** — ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The Purchaser In the Notes Section Below.

	Required	**Witnessed**	**Observed**
Acceptance Criteria (2.1.13; 6.7.2, a):	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**
DC High-Potential Test (4.3.5.1.2)	❍	❍	❍
Rated Rotor Temperature-Vibration Test (4.3.5.2.1)*	❍	❍	❍
*(For Generators Not Receiving Complete Test)			
Unbalance Response (4.3.5.3)	❍	❍	❍
Bearing Housing Natural Frequency Tests (4.3.5.4)	❍	❍	❍
Certification of Materials (4.2.1.1, a)	❍	❍	❍
Final Assembly Running Clearances (4.2.1.1, e)	❍	❍	❍
Material Inspection (4.2.2)	❍	❍	❍
Radiographic Test (4.2.2.2) Parts ______	❍	❍	❍
Ultrasonic Test (4.2.2.3) Parts ______	❍	❍	❍
Ultrasonic inspection of shaft forging (2.4.5.1.8)	❍	❍	❍
Magnetic Particle Test (4.2.2.4) Parts ______	❍	❍	❍
Liquid Penetrant Test (4.2.2.5) Parts ______	❍	❍	❍
Certified Data Prior to Shipment (4.3.1.15; 6.7.2, a)	❍	❍	❍
Burn-in Testing of Rotating Element Mounted Electronic Components (2.5.3.3)	❍	❍	❍
Heat Exchanger Performance Verification Test (TEWAC Enclosures) (4.3.5.5)	❍	❍	❍
Other: ______	❍	❍	❍
______	❍	❍	❍
______	❍	❍	❍

NOTES

API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 1 OF 11

		Rev
1	FOR / USER ______ DRIVEN EQUIPMENT ______	
2	SITE / LOCATION ______ QUANTITY ______	
3	SUPPLIER ______ ▽ SUPPLIER PROJECT NO. ______	
4	ITEM NAME ______	
5	Applicable To: ❍ Proposal ❍ Purchase ❍ As Built	
6	**GENERAL**	
7	NOTE: **(Alpha key code)** ❍ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**	
8	**Bold Type Indicates Typical Selection**	
9	**Basic Data:**	
10	Applicable Standards (1.3.1; 1.3.2; 1.6): ❍ **North American (i.e., ANSI, NEMA)** ❍ International (i.e., IEC, ISO)	
11	Nameplate Power (2.2.1.1): ______ kW ______ RPM (Synchronous)	
12	______ Volts (2.2.1.2) 3 Phase ______ Hertz Duty: ❍ Continuous ❍ Other ______	
13	Rated PF: ______ Insulation Class: ______ Voltage and Frequency Variations (2.2.1.2.1) ______	
14	Stator Temperature Rise (2.3.1.1) ______ °C Above ______ °C By RTD	
15	Rotor Temperature Rise ______ °C Above ______ °C By Resistance ❍ Sealed Exciter Windings Required (2.3.1.6)	
16	☐ Manufacturer's Type ______ ☐ Frame Size ______	
17	Other: ______	
18	**Site Data (2.1.2):**	
19	Area Classification (2.1.8): ❍ Nonclassified ❍ Classified as: Class ______ Group ______ Division ______ Autoignition Temp ______ °C	
20	Class ______ Group ______ Zone ______ Temperature Code ______	
21	Maximum Sound Pressure Level (2.1.3): ❍ **85 dBA @ 1 m. NO-LOAD, FULL VOLTAGE/FREQUENCY, SINE WAVE POWER** ❍ ______ dBA	
22	Ambient Temperature: Max ______ °C Min ______ °C	
23	Relative Humidity: Max ______ % Min ______ %	
24	Generator Location: ❍ Indoor ❍ Outdoor Roof Over Generator: ❍ Yes ❍ No	
25	Building Temperature Controlled: ❍ Yes ❍ No Site Elevation: ______ m	
26	Nonmassive Foundation (2.4.6.1.2), Description ______	
27	**Unusual Conditions:**	
28	Dust (2.4.1.2.2,c) ______ Chemicals (2.1.2) ______	
29	Seismic Loading (2.4.2.2) ______ Corrosive Agents (2.4.10.1.2) ______	
30	Other: ______	
31	**Explosion Protection Labeled Generator:**	
32	Explosion Protection Standard Label ❍ Ex (Canada) ❍ EEx (CENELEC) ❍ AEx (US) ❍ Other ______	
33	❍ Ex n (Non-Sparking) ❍ Ex p (Pressurization) ❍ Ex d (Flameproof) ❍ Other ______	
34	❍ Third Party Certification Required ❍ ATEX ❍ Other ______	
35	**Enclosure (2.4.1.2.1):**	
36	❍ Weather Protected (WP) (2.4.1.2.2) ❍ Type 1 ❍ Type II	
37	Air Filters: ❍ Provision Only (3.5.2) ❍ Required (3.5.4) ❍ **90%, 10 µm** ❍ Other ______	
38	▷ Manufacturer ______ ▷ Type ______ ▷ Model ______	
39	Differential Pressure Switch (3.5.5): ❍ Provision Only ❍ Required ❍ Differential Pressure Guage (3.5.5)	
40	▷ Manufacturer ______ ▷ Type ______ ▷ Model ______	
41	❍ Explosion Proof ❍ TEFC (2.4.1.2.3) ❍ Drip Proof Guarded ❍ TEPV (2.4.1.2.3) ❍ Other ______	
42	❍ TEAAC (2.4.1.2.3) Tube Materials (2.4.10.8,a): ❍ Copper ❍ Copper Alloy	
43	❍ Aluminum Alloy ❍ Stainless Steel ❍ Other ______	
44	Notes: ______	
45	______	

	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 2 OF 11

GENERAL (CONTINUED)

Rev

NOTE: (Alpha key code) ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Enclosure (2.4.1.2.1) (Continued):

○ TEWAC (2.4.1.2.4) Tube Materials (2.4.10.8, b): ○ **Cu-Ni** ○ Other ____

Redundant Coolers (2.4.1.2.4, b): ○ Yes ○ No Exchanger Location/Orientation (2.4.1.2.4, c) ____

Cooling Water Conditions per 2.4.1.2.4, a: ○ Yes ○ No (Other) ____

□ Water Flow (l/m) Max ____ Min ____ □ Water Pressure (kPa) Max ____ Min ____

Tube Construction (2.4.1.2.4, d; 2.4.10.8, c): ○ **Single Tube** ○ Double Tube

○ Flow Sensor Local Indicator Required (2.4.1.2.4, g) Relay Contacts: ○ NO ○ NC

○ Air Temperature Sensor Required (2.4.1.2.4, h), Type ____

○ Leak Detection Required ○ **Inner** ○ Outer ▷ Type and Description ____

▽ High Flow Alarm Set Point ____ l/m ▽ Low Flow Shutdown Set Point ____ l/m

○ Provision for Pre-Start Purging (2.4.1.1, e) ____ ○ Marine Grade Stainless Steel Fasteners (2.4.1.1, c)

○ Degree of Protection IP (2.4.1.2.1) IP ____ ○ Method of Cooling IC (2.4.1.2.1) IC ____

Other: ____

Mounting:

○ Horizontal: ○ Foot Mounted ○ Flange Mounted ▷ Flange Details ____

○ Vertical: ○ Shaft Up ○ Shaft Down

○ Pedestal ○ Axial Stator Shift Required (2.4.2.15)

○ Engine Type Bearings Furnished By ____ Shaft Furnished By ____

○ Baseplate: Furnished By (2.4.2.6): ____ ○ Soleplate: Furnished By (2.4.2.6): ____

○ Special Connections for Field Piping (2.4.3.1): ____

▽ When Rotor Dynamic Analysis Is Specified, List of Foundation Data Required From Purchaser (2.4.6.1.2): ____

Electrical System:

Primary Power Source ____ Volts ____ Phase ____ Hertz Maximum Ground Fault ____ Amps

Method of System Grounding (3.6.2.3) ○ Resistance ○ Reactance ○ Ungrounded ○ Solid

Fault Current at Machine Terminals (3.1.2) ____ MVA Let-Through Energy (3.1.2): ____ I^2t (Ampere-squared seconds)

○ Parallel Operation Requirements with Existing Equipment, Define: ____

Other: ____

Bearings:

Bearing Type: ○ **Hydrodynamic (2.4.7.1.1)** ○ Split Sleeve (2.4.7.1.2) ○ Tilting Pad (2.4.7.1.2) ○ Oil Ring Required (2.4.8.1)

○ Antifriction (2.4.7.1.3)

○ Thrust Bearing (2.4.7.1.5) Max Driver Thrust Downthrust Momentary ____ kg Upthrust Momentary ____ kg

Continuous ____ kg Continuous ____ kg

○ Bearing Constant-Level Sight Feed Oilers Required (2.4.7.2.2) Type: ____

○ Special Seals for Gas Purge (2.4.7.3, a) ○ Non-conducting Seals (2.4.7.3, b)

Notes: ____

SYNCHRONOUS GENERATOR
API 546 3RD Edition -- DATA SHEETS
METRIC UNITS

JOB NO. ________ ITEM / TAG NO. ________
PURCHASE ORDER NO. ________
REQ. / SPEC. NO. ________
REVISION NO. ________ DATE ________ BY ________
PAGE 3 OF 11

Rev

LUBRICATION SYSTEM

NOTE: (Alpha key code) — ○ TO BE COMPLETED BY PURCHASER (m or l) — □ BY MANUFACTURER WITH PROPOSAL (o or n) — ▽ BY MANUFACTURER AFTER ORDER (s or q) — ▷ BY MANUFACTURER OR PURCHASER (w or u)

Bold Type Indicates Typical Selection

▷ **SELF-LUBE (2.4.8.1)** ▷ Pressurized Lube Required (2.4.8.1) System Supplied By (2.4.8.4): ________ ○ Common With Driver

○ Per API 614: ________ -purpose oil system (2.4.8.6) ○ Main Oil Pump Required: ○ Integral Shaft Driven ○ Separate

○ Oil Rings Not Provided

▷ Type/Viscosity of Oil (2.4.8.8) ________ ▷ Pressure (2.4.8.4; 2.4.8.5) ________ kPa

▽ Total Bearing Oil Requirements (6.2.3): ▽ ________ l/m ▽ ________ kPa ▽ Heat Loss To Be Removed ________ kW

Antifriction Bearings: ▷ Grease: Type ________ Oil Mist (2.4.7.4.1) ○ Pure mist ○ Purge mist

Other: ________

SPECIAL CONDITIONS

○ Shaft and Spider one piece forging for 4 or more poles (2.4.5.1.2, b; 2.4.5.1.4)

○ Special Vibration Requirements (4.3.3.10) ________

○ Efficiency Evaluation Factor (EF) (6.2.1) ________ (value) ________ (currency) /kW applied at ________ % of F.L.

○ National, State / Provincial, or Local Codes (2.1.8): ________

○ External Forces on Generator Housing That May Affect Site Performance (2.1.13; 2.4.4): ________

○ Special Overspeed Requirement (2.4.5.2.7): ________

Other: ________

MAIN CONDUIT BOX

Main Terminal Box (3.1.1):

○ Box Location ________ Conductor Size ________ Type ________ Insulation ________ Qty. Per Phase ________

○ Quick Disconnect Type Bushing Studs or Receptacles (3.1.6, f) ________

○ Space for Termination of Shielded Cables (3.1.6, e) Cable Entering From (3.1.4): ○ Top ○ Bottom ○ Drive Side ○ Non-Drive End Side

○ Both Ends of Stator Winding Brought Out To Terminal Box (2.2.2.2) ○ Thermal Insulation (3.1.6, a)

Cable Between Stator Windings and Main Terminals (2.3.1.11): ○ Yes ○ No Description: ________

○ Space Heaters (3.1.6, b): ○ Temp. Code ________ ________ Volts ________ Phase ________ Hz □ ________ kW

○ Differential Protection Current Transformers (2.2.2.2; 3.1.6, h; 3.1.8; 3.6.3): Accuracy Class ________ Ratio ________ Quantity ________

Type: ○ Self-balancing ○ Full Differential ▷ Supplied By ________ ▷ Mounted By ________

○ Surge Capacitors (3.1.6, g; 3.6.2.1): ○ Microfarads ________ ▷ Supplied By ________ ▷ Mounted By ________

○ Surge Arresters (3.1.6, g; 3.6.2.2): ○ kV Rated ________ ▷ Supplied By ________ ▷ Mounted By ________

○ Current Transformers (3.1.6, h) for Ammeter ○ Accuracy Class ________ ○ Ratio ________ ○ Quantity ________

▷ Supplied By ________ ▷ Mounted By ________

○ Potential Transformers (3.1.6, j) for Voltmeter ○ Accuracy Class ________ ○ Ratio ________ ○ Quantity ________

○ Fuses Required ▷ Supplied By ________ ▷ Mounted By ________

○ Provision for Purging (3.1.6, c)

○ Removable Links (3.1.6, d) ○ Silver- or Tin- Plated Bus Joints (3.1.6, i) ○ Ground Bus (3.1.6, k)

○ Insulated Terminations and Interior Jumpers (3.1.6, m)

Notes: ________

API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 4 OF 11

1 **ACCESSORIES** Rev

2 NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

3 **Bold Type Indicates Typical Selection**

4 ○ **Frame Space Heaters (3.4):** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase □ ____ kW

5 ○ **Bearing Housing Heaters (2.4.8.3):** Temp. Code ____ Type ____ ____ Volts ____ Phase □ ____ kW

6 ○ **Exciter Space Heaters:** Temp. Code ____ Sheath Material ____ ____ Volts ____ Phase □ ____ kW

7 **Winding Temperature Detectors (3.2.1):** ○ **Three Per Phase, 3 Wire Platinum, 100 Ohms at 0°C** ○ Ground One Common Lead (3.2.1.2)

8 ○ Other Detector: Qty / Phase ____ Type ____ Material ____ Wires ____

9 ○ Thermocouples: Qty / Phase ____ Type ____

10 ▽ Recommended Settings: Alarm ____ °C Shutdown ____ °C

11 **Monitors and Devices** ○ Monitor for Shaft Grounding Brush Replacement (2.4.7.1.9)

12 ○ Test Device For Rotating Electronic Components (2.5.3.8) ○ Rotating Diode Failure Detection (2.5.3.12)

13 ○ Online Rotor Monitoring System (2.5.3.10): Description: ____

14 **Exciter Power Supply** ○ Permanent Magnet Generator (2.5.3.13) ○ Constant Voltage Transformer (2.5.1.5) ○ Phase Controlled Rectifier (2.5.1.5)

15 ○ Other (2.5.1.5) ____

16 **Auxiliary Equipment Enclosures (3.1.4):** ○ Box Location (Facing Opposite Drive End) ____

17 Conduit/Cable Entry From: ○ Bottom ○ Other: ____

18 **Hydrodynamic & Thrust Bearing Temperature Devices (3.3):**

19 ○ Provision Only ○ Install per API 670 (3.3.1) ○ Other ____

20 ○ **RTD's (3.3.1)** Qty / Brg. ____ Type ____ Material ____ Wires ____ ○ Ground One Common Lead (3.2.1.2)

21 ○ Thermocouple: Qty / Brg. ____ Type ____ Material ____ Wires ____

22 ○ Dial Type Thermometers (2.4.7.1.16): Type ____ ○ Alarm Contacts Number of Contacts ____ ○ NO ○ NC

23 Location of Bearing Temperature Sensor Wire Terminations ▷ Terminal box at generator side ▷ In the Stator RTD T Box ▷ Conduit Head at Bearing

24 ▽ Bearing Temperature Recommended Settings: Alarm ____ °C Shutdown ____ °C

25 ▽ Thrust Bearing Temp. Recommended Settings: Alarm ____ °C Shutdown ____ °C

26 **Vibration Detectors (3.8):** **Generators 1200 rpm and higher** Installed Qty / Bearing: ○ **TWO (3.8.1)** ○ Four (3.8.2)

27 Phase Reference Probe (3.8.1): ○ Provisions Only ○ **INSTALLED**

28 **Generators less than 1200 rpm** Installed Qty / Bearing: ○ Two (3.8.1) ○ Four (3.8.2)

29 Phase Reference Probe (3.8.1): ○ Provisions Only ○ Installed

30 Vibration Probe Leads Protected by (3.8.1.1; 3.9.1; 3.9.2): ○ Liquidtight Flexible Metal Conduit, Length ____ m

31 ○ Other Description: ____

32 ▷ Probe, Oscillator-Demodulator Mfr. ____ Model / Series ____

33 ▷ Probe Supplied By ____ Installed by ____ ▷ Osc.-Demod. Furnished By ____ Installed by ____

34 Bearing Housing Seismic Sensors (3.8.3) ○ Provisions Only ○ Installed Sensor Type ____ Sensor Mfr. ____

35 Qty / D.E. Bearing ____ Location (H, V, A) ____ Qty / N.D.E. Bearing ____ Location (H, V, A) ____

36 ▷ Sensor Supplied By ____ Installed by ____ ▷ Transducer Furnished By ____ Installed by ____

37 Location of Vibration Sensor Wire Terminations: ▷ Terminal box at generator side ▷ Within Sensor Housing ▷ Other ____

38 Vibration Switch: ○ Manual Reset ○ Electric Reset Switch Type: ____ Model: ____

39 Terminal Head or Box (3.1.11) ____

40 **Alarm and Control Switches (3.6.1): SPDT 10 Amp 115 Volt** ○ DC Rated Contacts: ____ ○ **AC Rated Contacts:** ____

41 **Partial Discharge Detectors (3.6.4; 3.1.6, l)** ○ Yes Describe Required System: ____

42 ____

43 **Separately Powered Auxiliary Fan(s) (2.4.10.6.3): Driver Information (where applicable)** ▷ Standard No. ____

44 Quantity ____ Location ____ Encl. ____ kW ____ RPM ____ ____ Volts ____ Phase ____ Hertz

45 Quantity ____ Location ____ Encl. ____ kW ____ RPM ____ ____ Volts ____ Phase ____ Hertz

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 5 OF 11

CONTROLS Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

▽ IEEE Type ______ Excitation System, See IEEE 421.1

▽ Excitation System Voltage Response Ratio (Over A 0.5 Second Interval), Using the IEEE 421A Definition ______

______

▽ Excitation System Voltage Response Time, Per IEEE 421.1, Sec ______

▽ Exciter Ceiling Voltage, When Loaded by the Main Generator Rotor Field Resistance (at 100°C) ______ V DC

Generator Vendor to Furnish:

○ Synchronous Machine Regulator (Voltage Regulator) Mfr. ______ Model ______

Excitation System:

○ Permanent Magnet Generator Excitation Source

○ High Initial Response Excitation System Required

▽ Short circuit currents vs. time for three phase fault conditions, line to line and line to ground fault conditions (6.2.2.2, a).

Curve No. ______

▽ Transient (momentary) voltage regulation (6.2.2.2, b) during sudden application and removal of specified load:

Load kV ______ kvar ______ OVReg ______

▽ Total and single harmonic voltages expressed in percent of fundamental voltage for line to line and line to neutral (6.2.2.2, c) while unit operating at rated voltage, frequency and no load. ______

○ Power System Stabilizer Required (Applied to the Synchronous Machine Regulator) ______

Other: ______

○ Manufacturer's Standard Excitation Control (Includinng Application & Protection) Package

Mount Excitation Control Package in: ○ Purchaser's Switchgear ○ Vendor Furnished Panel

○ Separate Control Devices, as Checked, for Mounting in: ○ Purchaser's Switchgear ○ Vendor Furnished Panel

○ Completely Assembled Control Panel with Devices as Checked (3.6.5.2)

Devices Mounted on Front of Panel, Labeled as Indicated:

○ Frequency ______ Hz Scale

○ Ammeter (0 - 5 A), 0 - ______ A Scale

○ Voltmeter (0 - 150 VAC), 0 - ______ kV Scale, "GENERATOR VOLTAGE"

○ "POWER FACTOR" Meter, 0.80 - 1 - 0.80 Scale or ______ - ______ - ______ Scale

○ Ammeter, 0 - ______ Amps Scale, "EXCITER FIELD AMPERES"

○ Potentiometer, "EXCITER FIELD" ○ "EXCITER FIELD ON-OFF" Test Switch

○ Generator Field-Ground Relay, "MAIN FIELD GROUND" Type ______

○ Overcurrent Relays (3), Instantaneous, 0.5 - 2 A Range, Manufacturer ______ Catalog No. ______

○ Overtemperature Relay, 50 - 190°C Range, For Use with ______ Ohm RTD, "STATOR TEMPERATURE"

Manufacturer ______ Catalog No. ______

Quantity ______ Type ______

○ Alarm Panel ○ Automatic Power-Factor Controller (2.5.1.4) ○ VAR Controller (2.5.1.4)

○ Vibration Probe Monitors: Manufacturer ______ Model ______

○ Temperature Indicator, ______ °C

○ Synchronoscope, With Lights ○ Synchronism-Check Relay, Type ______

○ Automatic Synchronizer, Type ______

______

Other: ______

______

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 6 OF 11

CONTROLS (CONTINUED) Rev

NOTE: (Alpha key code) ○ TO BE COMPLETED BY PURCHASER (m or l) □ BY MANUFACTURER WITH PROPOSAL (o or n) ▽ BY MANUFACTURER AFTER ORDER (s or q) ▷ BY MANUFACTURER OR PURCHASER (w or u)

Bold Type Indicates Typical Selection

Devices Mounted on Front of Panel, Labeled as Indicated (Continued):

○ Automatic Voltage Regulator (Synchronous Machine Regulator)

○ Single ○ Dual with Null Adjustment ○ Dual with Automatic Matching Feature

○ Volts/Hertz Limiter

○ Other ______

Devices Mounted Inside Panel, Labeled to Coincide with Drawing Identification:

○ Control Power Transformer, Constant Voltage, ______ kVA, ______ V - 120 V Rated to Maintain 95 % Secondary Voltage with 50% Sag of Primary Voltage

○ Full-Wave Bridge, Silicon Rectifiers ______ A (Min of 125 % of Exciter Field Amperes), Convection Cooled

○ Contactor Exciter Field Current

○ Field Monitor Relay, to Switch and Signal on Loss of Field or Out of Step Condition

○ Auxiliary and Timing Relays, as Required ○ Surge Suppressors and Fuses, as Required

○ Terminal Blocks, Heavy Duty, Identified by Unique Numbers, Number as required with 20 % Spares ______

○ Switches required for Alarm and Control devices (3.6.1): Contacts: **AC** ______ DC ______

○ Control Panel Wiring Entrance: ○ Top ○ Bottom ○ Side

○ Other: ______

DRIVER EQUIPMENT INFORMATION

Prime Mover Equipment: Tag No. ______ Description ______ Location ______

▷ Furnish Performance Curves, Curve Numbers (6.2.2) ______

Driver Equipment Mfr. ______ Type / Model No. ______ RPM ______

Driver Connection to Load: ○ Direct Coupled ○ Through Gearbox

Speed-Increasing-Reducing Gear (2.2.3.2, c): Ratio ______ Gear GD^2 (2.2.3.2, c) ______ kg-m^2 at ______ rpm

Total Driver-Equipment GD^2 (2.2.3.2, c) ______ kg-m^2 at ______ RPM

Generator Shaft Extension (2.4.5.1.9): ○ Cylindrical Fit ○ Taper Fit ○ Flange ○ Other Coupling data ______

Rotation ***Viewed from Opposite Drive End of Generator:*** ▷ Clockwise ▷ Counterclockwise

Coupling (2.4.9.4): Type ______ Mfr. ______ Type / Model ______

▷ Manufacturer's Standard ▷ Per API 671

Coupling GD^2 (2.2.3.2, c) ______ kg-m^2 at ______ rpm Mass Moment of Coupling Half (2.4.6.2.2, f): ______ kg-m^2

Supplied By: ○ Generator Mfr. ○ Driver Equipment Mfr ○ Purchaser ○ Others ______

Mounted By: ○ Generator Mfr. ○ Driver Equipment Mfr ○ Purchaser ○ Others ______

Other: ______

MISCELLANEOUS

○ Manufacturer's Standard Paint ○ Extra Coat at Shipment ○ User's Special Paint ______ ○ Outline for Special Weather Protection (6.2.14)

○ Proof of Nonsparking, Corrosion-Resistant Fan (2.4.10.6.1) ○ Quantity of Special Tools and Lifting Required (2.1.12; 2.4.2.13): ______

▷ Special Low-Temp Material Requirements (2.4.10.4) ______

▷ Special Winterizing Requirements (6.2.14) ______

○ Materials To Be Identified With ANSI, ASTM, or ASME Numbers (6.2.17) ______

○ Typical Drawings & Literature with Proposal ○ Electronic Instruction Manuals (6.6.1) Qty: ______ ○ Photos showing assembly steps required (6.8.5)

○ Performance Curves Supplied in Digitial Format (6.6.1) Digitial Format Description: ______

○ Manufacturer To Supply Curve Data in Tabular Format (6.6.1) ○ NRTL Certification (6.8.6) Qty: ______ ○ PMI Certification (6.8.6) Qty: ______

○ Detailed instructions and photographs for disassembly and inspection (6.8.4, c) Qty: ______ ○ Certified Drawings (6.6.2) Qty: ______

Other: ______

SYNCHRONOUS GENERATOR
API 546 3RD Edition -- DATA SHEETS
METRIC UNITS

JOB NO. ______ ITEM / TAG NO. ______
PURCHASE ORDER NO. ______
REQ. / SPEC. NO. ______
REVISION NO. ______ DATE ______ BY ______
PAGE 7 OF 11

MISCELLANEOUS (CONTINUED) Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection Nameplate Material (2.4.11.1): ○ **Stainless Steel** ○ Other ______

○ Type Tests and Design Information Verifying All Gasket Materials are Impervious to Lube Oil and Chemicals (3.1.4), Qty of Type Tests Documentation ____

○ Special Identification for Transmittals (6.4.2, e) ○ Separate Nameplate with Purchaser's Information (2.4.11.4)

______ ______

______ ______

Shipment (4.4.1): ○ Domestic ○ Export ○ Export Boxing Required ○ Commissioning Assistance Required (6.2.16) ○ Mounted on Skid (4.4.1, e)

○ Special Shipping Bearings (4.4.1, k) ○ Outdoor Storage for More Than Six Months (4.4.1) ○ Piping Assembled (4.4.1, h)

○ Electronic Vibration Test Data (4.3.3.15) Digital Format Description: ______ Qty: ____

○ Provide Separate Price For Each Optional Test (6.2.13)

Other: ______

GENERATOR DATA - FIRST SECTION

☐ Manufacturer ______ ☐ Type / Model No. ______ ☐ Frame Size / Designation ______

Qty. ____ ______ kW ______ RPM (Syn.) ______ Poles ______ Volts ______ Phase ______ Hz

Insulation Class ______ Temperature Rise Class CLASS B Enclosure ______

Rated Speed ______ RPM Rotor GD^2 (6.2.2.2, d) ______ kg-m^2

☐ **Calculated Expected Data (6.2.2.2, f) at the following Loads:**

Load Point	50%	75%	100%	○ Other: ____ %
Efficiency	____ %	____ %	____ %	____ %
Power Factor	____ %	____ %	____ %	____ %
Current	____ Amps	____ Amps	____ Amps	____ Amps

○ Guaranteed Efficiencies (6.2.2.2, g) at the following Loads: ▷ Test Method (6.2.2.2, f): ______

Load Point	25%	50%	75%	100 %	○ Other: ____ %
Efficiency	____ %	____ %	____ %	____ %	____ %
Power Factor	____ %	____ %	____ %	____ %	____ %
Current	____ Amps	____ Amps	____ Amps	____ Amps	____ Amps

☐ Short Circuit Currents vs. Time (6.2.2.2, a) Curve No. ______

☐ Transient Voltage Regulation (6.2.2.2, b) at:

100% Load Addition and Load Removal: ______

▷ Other: ____ % Load Addition and Load Removal: ______

☐ Synchronizing Power (6.2.2.2, h) at No Load ______ Pr ☐ Synchronizing Power (6.2.2.2, h) at Full Load ______ Pr

☐ Rated Generator Field: ____ Amps ____ Volts ☐ Reactive Capability Curve No. ______

☐ Rated Exciter Field: ____ Amps ____ Volts ○ Calculated Rotor-Response (6.7.2, b) ☐ Curve Nos. (6.7.2, b): ______

☐ Max. Sound Pressure Level (2.1.3) ____ dBA @ 1 m, no-load

☐ Weights: Net: ______ kg Stator ______ kg Rotor ______ kg Shipping ______ kg

Rotor Construction: ☐ Solid Cylindrical ☐ Laminated Cylindrical ☐ Salient-Pole Solid

☐ Salient-Pole "Star" Punching Type, Shrunk Onto Shaft ☐ Salient-Pole Laminated/Bolted

☐ Salient-Pole Dove-Tail or T-Tail Attachment to Shaft ☐ Other ______

☐ Minimum % Overspeed (2.1.5; 2.4.5.2.7) ______

Other: ______

______

______

______

______

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 8 OF 11

No.	GENERATOR DATA - SECOND SECTION	Rev
1	**GENERATOR DATA - SECOND SECTION**	
2	NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** ☐ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**	
3	**Bold Type Indicates Typical Selection**	
4	**Bearings:**	
5	Bearing Type Required: ▷ Hydrodynamic (2.4.7.1.1) ▷ Oil Rings Required (2.4.8.1) ▷ Antifriction (2.4.7.1.3)	
6	Thrust Bearings, Maximum Connected Equipment Thrust (2.4.7.1.11) ______	
7	Bearing, Drive End: Capable of Self-Lube ______ Manufacturer ______ Type ______ Model / Part No. ______	
8	Bore Diameter: Min ______ mm Max ______ mm Bore Length ______ mm	
9	Design Clearance with Shaft: Min ______ mm Max ______ mm Bearing Loading: ______ kPa	
10	Bearing, Non-Drive End: Capable of Self-Lube ______ Manufacturer ______ Type ______ Model / Part No. ______	
11	Bore Diameter: Min ______ mm Max ______ mm Bore Length ______ mm	
12	Design Clearance with Shaft: Min ______ mm Max ______ mm Bearing Loading: ______ kPa	
13	Thrust Bearing: ☐ Non-Drive End Manufacturer ______ Type ______ Model / Part No. ______	
14	☐ Drive End Bearing Loading: ______ kPa	
15	▷ Special Seals for Gas Purge (2.4.7.3) ______	
16	Other: ______	
17	○ Provide Generator Preliminary Parameters With Proposal (6.2.2.3), State Per Unit Values, Generator: ______ kVA Base at Rated Voltage and 25^{0}C	
18	☐ X_{dv}'' Rated Voltage (Saturated) Subtransient Reactance ______	
19	☐ X_{2v} Rated Voltage (Saturated) Negative-Sequence Reactance ______	
20	☐ T_{a3} Rated Voltage (Saturated) Armature Time Constant ______ Sec.	
21	☐ Rated MVA ______ ☐ Rated Terminal Voltage ______ kV	
22	▽ **Generator Parameters (State Per Unit Values, Generator ______ kVA Base at Rated Voltage and 25^{O}C):**	
23	X_l Armature Leakage Reactance ______	
24	X_{ad} Direct Axis Armature Reactance ______	
25	X_d Direct Axis Synchronous Reactance (Saturated) ______ Un-Saturated ______	
26	X_p Potier Reactance ______	
27	X'_d Direct Axis Transient Reactance (Saturated) ______ Un-Saturated ______	
28	X''_d Direct Axis Subtransient Reactance (Saturated) ______ Un-Saturated ______	
29	X_{aq} Quadrature Axis Armature Reactance ______	
30	X_q Quadrature Axis Synchronous Reactance (Saturated) ______ Un-Saturated ______	
31	X_f Field Leakage Reactance ______	
32	X'_q Quadrature Axis Transient Reactance (Saturated) ______ Un-Saturated ______	
33	X''_q Quadrature Axis Subtransient Reactance (Saturated) ______ Un-Saturated ______	
34	X_{kq} Quadrature Axis Amortisseur Reactance (Slip = 1.0) ______	
35	X_{kd} Direct Axis Amortisseur Reactance (Slip = 1.0) ______	
36	X_0 Zero Sequence Reactance (6.2.2.2, e) ______	
37	X_2 Negative Sequence Reactance (Saturated) ______ Un-Saturated ______	
38	R_a Stator Armature Resistance/Phase ______	
39	R_f Field Resistance (Without FDRs) ______	
40	R_{fr} Field Resistance (With FDRs) ______	
41	R_{kq} Quadrature Axis Amortisseur Resistance (Slip = 1.0) ______	
42	R_{kd} Direct Axis Amortisseur Resistance (Slip = 1.0) ______	
43	R_0 Zero Sequence Resistance ______	
44	R_1 Positive Sequence Resistance ______	
45	R_2 Negative Sequence Resistance ______	

	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ____ ITEM / TAG NO. ____ PURCHASE ORDER NO. ____ REQ. / SPEC. NO. ____ REVISION NO. ____ DATE ____ BY ____ PAGE 9 OF 11

GENERATOR DATA - SECOND SECTION (CONTINUED) — Rev

NOTE: **(Alpha key code)** — ◯ TO BE COMPLETED BY PURCHASER **(m or l)** — □ BY MANUFACTURER WITH PROPOSAL **(o or n)** — ▽ BY MANUFACTURER AFTER ORDER **(s or q)** — ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

T_a Armature Short-Circuit Time Constant, Sec ____

T'_{do} Direct Axis Transient Open-Circuit Time Constant, Sec ____

T'_{qo} Quadrature Axis Transient Open-Circuit Time Constant, Sec ____

T''_{do} Direct Axis Subtransient Open-Circuit Time Constant, Sec ____

T''_{qo} Quadrature Axis Subtransient Open-Circuit Time Constant, Sec ____

T'_d Direct Axis Transient Short-Circuit Time Constant, Sec ____

T''_d Direct Axis Subtransient Short-Circuit Time Constant, Sec ____

C_w Winding Capacitance to Ground, Microfarads/Phase ____

I_2^2t Limit ____

Other: ____

STATOR & ROTOR WINDING REPAIR DATA

▽ **Stator Coil Information:**

Total Copper Weight ____ kg Copper Strand Size ____ Insulation ____

Number of Strands per Coil Turn ____ Turn Insulation Description ____

Number of Turns per Coil ____ Coil Ground-Wall Insulation Description ____

Coil Configuration ____ Rows by ____ Columns

Finished Coil Dimension in Slot Region, W x H x L (Also Give Tolerances): ____

Total Number of Stator Slots ____ Winding Throw ____ Winding Connection ____

Slot Filler Description - Thickness: Top ____ Side ____ Between Top-Bottom Coils ____

Stator Bore Diameter ____ Slot Dimensions ____ Stress Grading if Applicable ____

Special End-Turn Bracing ____

Coil Dimensional Drawing No. ____ Thickness Groundwall Insulation ____ mm

Thickness Turn Insulation ____ mm Thickness Strand Insulation ____ mm

Other: ____

▽ **Rotor Winding Information:**

Total Copper Weight ____ kg Strand or Bar Size ____ Conductor Material ____

Insulation Description ____

General Description of Winding (Number of Turns, Formed Coil, size, Etc,) ____

Damper Winding Description, If Applicable ____

Retaining Ring Alloy, If Applicable ____

Ring Material ____ Ring Dimensions Premachining ____

Shaft Material ____

Other: ____

SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______	PAGE 10 OF 11

ANALYSIS, SHOP INSPECTION, AND TESTS Rev

NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**

Bold Type Indicates Typical Selection

Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The Purchaser In the Notes Section Below.

	Required	Witnessed	Observed
Acceptance Criteria (2.1.13; 6.7.2, a):	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**
Coordination Meeting (6.3)	●		
Design Review (6.5)	○		
Torsional Analysis (2.4.6.2.7) By ______	○		
Lateral Critical Speed Analysis (2.4.6.2.1)	○		
Review of Quality Control Program (4.2.3.4)	○		
Submit Test Procedures 6 Weeks Before Tests (4.3.1.5)	○		
Inspection for Cleanliness per API 614 (4.2.3.2; 4.2.3.3)	○	○	○
Observance of Assembly/Dismantling (4.3.1.1)	○	○	○
Demonstrate Accuracy of Test Equipment (4.3.1.16)	○	○	○
Stator Core Test (4.3.4.1)	○	○	○
Surge Comparison Test (4.3.4.2)	○	○	○
Special Surge Test of Coils (4.3.4.2.1)	○	○	○
Sacrifical Coils Cut Into Segments (4.3.4.2.1, c)	○	○	○
Number of Segments Cut Each Coil __ Cuts in: Straight Section __ Bends __			
Partial Discharge Test (4.3.4.6)	○	○	○
Balance in Minimum of 3 Planes (2.4.6.3.1)	○	○	○
Dynamic Balance Rotors 600 rpm and Above (2.4.6.3.1)	●	○	○
Final Balance (4.3.1.6.1)	○	○	○
Component Balance for > 4 Pole (2.4.6.3.1)	○	○	
Residual Unbalance Verification Test (2.4.6.3.6)	○	○	○
Balance Check with Half Coupling (2.4.6.3.3)	○	○	○
Running Tests with Coupling Half (2.4.6.3.3; 4.3.1.6)	○		
Stator Inspection Prior to VPI (4.3.4.5)	○	○	○
Sealed Winding Conformance Test (4.3.4.4)	○	○	○
Power Factor Tip-Up Test (4.3.4.3)	○	○	○
Routine Test (4.3.2)	●	○	○
Insulation Resistance Using Table 7 (4.3.2.1, d)	○	○	○
Bearing Dimensional & Alignment Checks Before Tests (4.3.2.1, j)	○	○	○
Bearing Dimensional & Alignment Checks After Tests (4.3.2.1, k)	○	○	○
Vibration Monitoring and Recording (4.3.3.6; 4.3.3.8)	○	○	○
Complete Test (4.3.5.1.1)	○	○	○
Efficiency (4.3.5.1.1, a)			
Open/Short-Circuit Saturation (4.3.5.1.1, c)			
Heat Run (4.3.5.1.1, d)			
Exciter Heat Run (4.3.5.1.1, e)			
No Load V-Curve (4.3.5.1.1, f)			
Sound Pressure Level Test (4.3.5.1.1, g)			

Other: ______

energy API	SYNCHRONOUS GENERATOR API 546 3RD Edition -- DATA SHEETS METRIC UNITS	JOB NO. ______ ITEM / TAG NO. ______ PURCHASE ORDER NO. ______ REQ. / SPEC. NO. ______ REVISION NO. ______ DATE ______ BY ______ PAGE 11 OF 11

#		Required	Witnessed	Observed	Rev
1	**ANALYSIS, SHOP INSPECTION, AND TESTS (CONTINUED)**				
2	NOTE: **(Alpha key code)** ○ TO BE COMPLETED BY PURCHASER **(m or l)** □ BY MANUFACTURER WITH PROPOSAL **(o or n)** ▽ BY MANUFACTURER AFTER ORDER **(s or q)** ▷ BY MANUFACTURER OR PURCHASER **(w or u)**				
3	**Bold Type Indicates Typical Selection**				
4	**Analysis, Shop Inspection And Tests Apply to All Machines in a Multiple Machine Order Unless Specifically Stated Otherwise By The**				
5	**Purchaser In the Notes Section Below.**				
6		**Required**	**Witnessed**	**Observed**	
7	**Acceptance Criteria (2.1.13; 6.7.2, a):**	**(4.1.1; 4.1.3.3; 4.3.1.1)**	**(4.1.3; 4.1.3.1; 4.3.1.1)**	**(4.1.3; 4.1.3.2; 4.3.1.1)**	
8	DC High-Potential Test (4.3.5.1.2)	○	○	○	
9	Rated Rotor Temperature-Vibration Test (4.3.5.2.1)*	○	○	○	
10	*(For Generators Not Receiving Complete Test)				
11	Unbalance Response (4.3.5.3)	○	○	○	
12	Bearing Housing Natural Frequency Test (4.3.5.4)	○	○	○	
13	Certification of Materials (4.2.1.1, a)	○	○	○	
14	Final Assembly Running Clearances (4.2.1.1, e)	○	○	○	
15	Material Inspection (4.2.2)	○	○	○	
16	Radiographic Test (4.2.2.2) Parts ______	○	○	○	
17	Ultrasonic Test (4.2.2.3) Parts ______	○	○	○	
18	Ultrasonic inspection of shaft forging (2.4.5.1.8)	○	○	○	
19	Magnetic Particle Test (4.2.2.4) Parts ______	○	○	○	
20	Liquid Penetrant Test (4.2.2.5) Parts ______	○	○	○	
21	Certified Data Prior to Shipment (4.3.1.15; 6.7.2, a)	○	○	○	
22	Burn-in Testing of Rotating Element Mounted Electronic Components (2.5.3.3)	○	○	○	
23	Heat Exchanger Performance Verification Test (TEWAC Enclosures) (4.3.5.5)	○	○	○	
24	Other: ______	○	○	○	
25	______	○	○	○	
26	______	○	○	○	
27	**NOTES**				
28	______				
29	______				
30	______				
31	______				
32	______				
33	______				
34	______				
35	______				
36	______				
37	______				
38	______				
39	______				
40	______				
41	______				
42	______				
43	______				
44	______				
45	______				

Annex C

Vendor Drawing and Data Requirements

SYNCHRONOUS MACHINE VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______________ ITEM NO. ________________________
PURCHASE ORDER NO. ________ DATE ________________________
REQUISITION NO. _____________ DATE ________________________
INQUIRY NO. _________________ DATE ________________________
PAGE 1 OF 3 BY ______________________________

FOR ____
SITE ____
SERVICE ____

REVISION ____
UNIT ____
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 - Received from vendor
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	Due from vendor	Final - Received from vendor
			A.1 Dimensioned outline drawings with major and minor connections.					
			a. Primary equipment.					
			b. Auxiliary equipment.					
			c. Maintenance weights.					
			d. Size of shipping sections.					
			e. Sole plates.					
			f. Heat exchangers.					
			g.					
			h.					
			i.					
			j.					
			A.2 Foundation loading diagrams.					
			a.					
			b.					
			c.					
			A.3 Schematic wiring and/or flow diagrams.					
			a. Speed sensor.					
			b. Space heaters.					
			c. Locked rotor protection package.					
			d. Cooling and exchanger.					
			e. Lubrication (if applicable).					
			f. Vibration monitoring.					
			g. Temperature sensors.					
			h. Differential current transformers.					
			i. Phase current transformers.					
			j. Excitation/voltage regulation panel.					
			k.					
			l.					
			m.					
			n. .					

[a]Proposal drawings and data do not have to be certified or as-built.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

SYNCHRONOUS MACHINE VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. _______________ ITEM NO. ___________________________

PAGE 2 OF 3 BY _________________________________

DATE _________________ REV. NO. ______________________________

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

Proposal[a]	Review[b]	Final[b]	DESCRIPTION	Review - Due from vendor[c]	Review - Received from vendor	Review - Returned to vendor	Due from vendor[c]	Final - Received from vendor
			B.1 Detail drawings and cross-sectional drawings.					
			a. Shaft end details.					
			b.					
			c.					
			B.2 Erection/assembly drawings.					
			a.					
			b.					
			c.					
			B.3 Calculations-torsional/lateral response.					
			a.					
			b.					
			c.					
			B.4 Predicted performance curves.					
			a. Power factor versus speed.					
			b. Motor and rotor heating (I^2/T).					
			c. Torque versus speed at rated voltage.					
			d. Torque versus speed at _______ percent voltage.					
			e. Current versus speed at rated voltage.					
			f. Current versus speed at ______ percent voltage.					
			g. Expected efficiency.					
			h. Acceleration time curves.					
			i.					
			j.					
			k.					
			B.5 For generators; predicted performance curves, including the following.					
			a. Reactive capability curve					
			b. Capability versus air (water) cooling temperature outlet.					
			c. Saturation and synchronous impedance curves					
			d. Short circuit current decrement curves line to line; three phase; line to ground.					
			e.					
			f.					
			C.1 Manufacturer's data reports (as built).					
			C.2 Performance test reports.					

[a]Proposal drawings and data do not have to be certified or as-built.

[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.

[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

SYNCHRONOUS MACHINE VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. _______________ ITEM NO. ___________________________
PAGE 3 OF 3 BY ________________________________
DATE _________________ REV. NO. ______________________________

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 - Received from vendor
Due from vendor
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	Due from vendor	Final - Received from vendor
			C.3 Installation, maintenance, and operating instructions.					
			D.1 Recommended spare parts list.					
			a. Construction.					
			b. Start-up.					
			c. Maintenance (2-year).					
			E.1 Complete set of Assembly Photographs (see 6.8..5)					
			E.2 Complete NRTL certification (see 6.8..6)					
			E.3 Positive material identification material certification (see 6.8..6)					

[a]Proposal drawings and data do not have to be certified or as-built.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

Annex D

Motor Data Sheet Guide

The material in this annex offers a guide to the information on the data sheets in Annex A.

D.1 Purpose

This data sheet guide provides instructions for completing the API Synchronous Motor Data Sheet before obtaining bids. It also contains information to help evaluate data supplied by the Vendor. This data sheet guide presumes the specifying engineer meets the following requirements.

a) Is familiar with the process of procuring driver equipment. If not, the specifying engineer should refer to the Specifying and Purchasing Procedure section of this manual;

b) Is familiar with the purpose, format and use of data sheets.

This guide does not cover all possible applications. The specifying engineer must consider the specific installation when filling out the data sheet.

D.2 Scope

The Synchronous Motor Data Sheet covers all synchronous motors rated 500 HP and larger. See the generator data sheet guide, Annex F, for synchronous generators. The motor Data Sheets are in both metric (kW, kilogram etc.) and US customary (HP, pound) units. The line numbers listed in this guide refer to US Customary Units version of the data sheets and may vary from the metric units version.

The Synchronous Motor Data Sheet is based on API 546. Paragraph numbers corresponding to API 546 are indicated in (parentheses) on the data sheet where applicable. Features that are called up in the Standard as being the default for that particular item are listed in the Data Sheets as **BOLD**. The default for the item will be assumed by the vendor unless alternate selection is identified. Items for which there are no alternatives (e.g. Stainless steel nameplates) are not shown as options on the Data Sheets. If some other option is desired it should be listed under “Other".

D.3 Symbol Explanatory Page

The initial page of the Data sheet is used to explain how to insert or change the symbols used to mark selections in the digital form Data Sheet proper. The symbols are based on “Wingdings" font and are helpful when filling out the Data Sheets for digital transmission.

D.4 Page 1

Line 2 “Site/Location” Indicates the name of the plant or the equipment train identification.

Line 3 “Supplier” The manufacturer of the machine.

Line 3 “Supplier Project Number” The vendor’s internal identification.

D.4.1 General Information

Line 5 “Applicable to: Proposal, Purchase, or As-Built”—Check “proposal” when the data sheet is sent out for quotation, "purchase" when an order is placed, and "as-built" to reflect the completed data sheet after all design details and changes during the manufacture and testing of the motor have been completed.

D.4.2 Basic Data

Line 10 “Applicable Standards”—Indicate which standards apply, either North American or International.

Line 11 “Nameplate Power, Service Factor, Synchronous RPM” Power output of the motor, where known. This may be entered by the driven-equipment supplier, if the motor and driven-equipment are to be purchased as a package. A service factor of 1.0 is recommended. If output beyond the 1.0 service factor output rating is required, the next higher motor rating should be chosen. This is recommended to assure an adequate torque margin for the motor pull-in and pull-out torques. If a 1.15 service factor is specified, API 546 limits the temperature rise to 10 °C above the Class B rise to ensure long life when applied to a Class F winding insulation system. Enter the rated speed of the motor, where known. Available speeds can be calculated by the following equation:

$$\text{Speed(rpm)} = \frac{120 \times f}{p}$$

where

f is the power supply frequency in Hz; and

p is the number of magnetic poles in the motor (2, 4, 6, 8, ...).

Line 12 “Duty” Almost all petrochemical applications are continuous duty where the motor normally runs continually for long enough to reach thermal equilibrium, which takes some hours. The rare occasions where motors are not expected to reach equilibrium should be described.

Line 13 “Rated Power Factor” Commonly specified power factor ratings are 1.0 and 0.8 (overexcited). A 1.0 power factor rated synchronous motor is more efficient than a 0.8 power factor rating of equal mechanical output; perhaps up to one-half percent more efficient. Sometimes 0.8 power factor rated motors are used to correct plant power factor, but this usually can be accomplished more efficiently with power-factor-correction capacitors. A careful economic analysis should be made of the increased cost (approximately 25 %) of a 0.8 power factor motor over a 1.0 power factor motor compared with a capacitor installation. The most significant advantage of the 0.8 power factor rated motor is its increased “pull-out” torque. Pull-out torque is the maximum sustained torque a motor will develop at rated speed with rated voltage, frequency, and excitation applied. If the torque imposed by the driven load exceeds this torque, the motor will stall. Motors of 0.8 power factor rating have a pull-out torque rating of 200 % to 225 % of the full-load torque rating as compared to 150 % for a 1.0 power factor rated motor. If a severe power system voltage dip should occur, a 1.0 power factor motor is more likely to stall. The 0.8 power factor is also more likely to remain stable during power system faults (and not fall “out of step”) than a 1.0 power factor motor. If the motor is in unspared or critical service, specification of a 0.8 power factor may be justified. Otherwise, efficiency and first-cost considerations favor specifying a 1.0 power factor motor. The power factor should always be specified, even if the driven-equipment supplier is filling in the “Nameplate Power” and “Speed”.

Line 13 "Insulation Class” Class F insulation is the most common grade used and is rated for 155 °C operation. Class H insulation is rated for higher temperatures but is seldom practical for machines of these powers. Class B insulation is rated for lower temperature rise, and is now uncommon in these ratings. To improve durability, Class B temperature rise (see below) with a Class F system is usually specified so that the cooler running insulation will give long life.

Line 13 “Voltage and Frequency Variations” Enter voltage and frequency variations if beyond standard limits.

Line 14 “Motor Power Source” Sine Wave power is the fixed frequency utility supply. An ASD gives an adjustable frequency and voltage to adjust the motor speed. An LCI (load commutated inverter) is a type of ASD that requires that the motor run at a leading power factor. ASDs and LCIs sometimes require special winding configurations, and the type should be noted.

Line 15 – 16 "Stator Temperature Rise" and "Rotor Temperature Rise" This is the increase in temperature of the windings permitted over ambient air temperature. There are two methods used to determine the temperature rise: by resistance temperature detector (RTD) and by the measurement of the resistance change (RES), with temperature, of the winding itself. Use the following table to fill in the blank. Temperature rise by "RTD" is recommended when the motor stator is equipped with RTDs. If not equipped with RTDs, specify by resistance ("RES"). All field winding temperatures are determined by resistance.

Motor Rating or Part	Method	Class B Rise (Above 40 °C Ambient)
Stator Winding		
All HP ratings	RES	80 °C
1500 HP and less	RTD	90 °C
Over 1500 HP 7000 V and less Over 7000 V	 RTD RTD	 85 °C 80 °C
Field Winding		
Salient-pole motors	RES	80 °C
Cylindrical-rotor motors	RES	85 °C

The Class B rise given above is specified even though the insulation system is rated for the higher Class F temperature. This is to assure long insulation life. The cost associated with losses (life cycle costs—see Section E.1.1.19) also results in lower than Class B rise in most cases, since losses result in heat. The above values are for a maximum ambient air temperature of 40 °C. If the maximum ambient temperature is above 40 °C up to and including 50 °C, reduce the table values by 10 °C. If the maximum ambient temperature is above 50 °C up to and including 60 °C, reduce the table values by 20 °C. Note that the "Ambient" is taken as the temperature of the cooling air entering the motor. If a heat exchanger is used to cool the air, the ambient will be higher than the outside air or water entering the heat exchanger.

"Sealed Exciter Windings Required" Specify sealed exciter windings if there are concerns about excessive humidity, salt or petrochemical contamination.

D.4.3 Site Data

Line 20 – 21—Area Classification "Class__, Division__, Group__, or Zone___, Class___, Group___ or Nonclassified"—Use the Class, Division, and Group or Zone, Class, Group as defined in Chapter 5 of the *National Electrical Code* (NEC). Areas are normally defined for existing plants or projects. Refer to API 500 and API 505.

The most commonly specified area classifications are Class I, Division 2, Group D or Class 1, Zone 2, Group D for process areas. "Class I" means a flammable gas or liquid, "Division 2" is where the gas or vapor is present only during abnormal conditions, and "Group D" is a category of materials including gasoline. A "Division 1" area means the gas or vapor is present during normal operation and special enclosures or provisions for ventilation must be used. The IEC Zone system as outlined in NEC Article 505 uses Zone 2 as having the explosive mixture present only during abnormal conditions, similar to Division 2. Zone 1 is when the mixture is present often, and Zone 0 is when the mixture is present constantly. API 505 discusses the Zone system in more detail.

Line 20 "Autoignition Temperature" If nothing is entered, 250 °C is assumed for any ignitable vapors or gases that may exist around the motor while it is in service. Some liquids have ignition temperatures lower than 250 °C, and must be listed here. See the current edition of NFPA 497 for a complete listing of these liquids.

Line 22 "Maximum Sound Pressure Level" 85 dBA at full voltage unloaded on a sine wave is the default. Lower numbers may be desired by OH & S people, but are difficult and expensive to achieve.

Line 23 “Ambient Temperature” Minimum and maximum ambient air temperature. Significant, if below –15 °C (5 °F) or above 40 °C (104 °F). Low temperatures may determine the need for bearing housing oil heaters or special impact-resistant steel types. High temperatures may determine a derating factor for the motor design or may dictate a special oil cooling system.

Line 24 “Relative Humidity” Indicates the maximum and minimum humidity.

Lines 25 – 26 “Indoor: Temperature Controlled, Outdoor:, Roof, No Roof” Check as appropriate. Affects the selection of the housing. For example: Requiring a weatherproof housing. If Indoor Temperature Controlled, the operating ambient temperature of the motor may be different than the outdoor temperature.

Line 26 “Site Elevation” Significant if 3300 ft (1000 m) or more above sea level. Machines must be derated or specially designed for higher elevations above this because of the decreased air density.

Line 27 “Nonmassive Foundation Description” The foundation should be designed to meet the massive foundation criteria of 2.4.6.1.2. There may be certain installations where this is not possible, such as on offshore platforms. Detail these structures on the data sheet. A nonmassive foundation may affect the mechanical dynamic performance of the motor. Refer to the description of a massive foundation in API 546.

D.4.4 Unusual Conditions

Line 29 “Dust” If abrasive dust conditions are specified, winding insulation protection is required for drip proof or weather-protected enclosures. This treatment usually reduces the air-cooling effectiveness and raises the winding temperature above that without the treatment, resulting in a larger and more costly motor. Specify any other dust conditions here, such as adhering dust or corrosive dust. See the descriptions of Weather Protected Type I and II enclosures. Totally enclosed machines should be used where possible in these situations.

Line 29 “Chemicals” If the motor is subject to any specific chemicals, vapors, or liquids, specify what those chemicals are.

Line 30 “Seismic Loading” If the motor has significant ducting or unsupported piping (not recommended), indicate the maximum forces to which the frame will be exposed. For example: Uniform Building Code Seismic Zone 2.

Line 30 “Corrosive Agents” Include environmental exposure that could result in stress-corrosion cracking. This may include salt air or trace hydrogen-sulfide.

Line 31 “Other” Indicate any other unusual conditions. For example: Hose down or tropical environment.

Lines 32 – 35 For metric data sheets only: “Explosion Protection Labeled Motors” There are various standards which may apply to the use of machines in hazardous locations, the selection of applicable standards depends on the geographic location, the local requirements and user preference. Determine the requirements and specify if any listed lables are required for the particular application, and whether some form of third party certification is required.

D.4.5 Enclosure

Line 33 “Weather Protected; Type I, Type II” This is a common enclosure. Air from outside the motor is passed through its interior for cooling active parts. Use the weather Protected Type II (WP II) for outdoor applications. The WP II machine is constructed so that high-velocity air and dirt ingested by the motor can be discharged without entering the internal air passages to the electric parts of the motor. Use the Weather Protected Type I (WP I) for sheltered locations that may be subject to some weather intrusion or water spray. The WP II and WP I enclosures may not be an appropriate choice where adhering dust is present or if the area does not have free air exchange. The hot air discharged from the motor can cause a closed-in area to become excessively hot. WP machines with a rated voltage over 4000 Volts may have a shorter insulation life due to tracking.

NOTE API recommends utilizing TEEAC or TEWAC enclosures for machines rated 6 kV and above.

Line 34 "Air Filters" Filters are recommended for WP machines. The standard recommended filter captures 90 % of 10 micron dust particles. A Differential Pressure Switch or Gauge (see Line 36 below) is recommended to annunciate blocked filters.

Line 36 "Differential Pressure Switch, Gauge" The easiest way to tell if the filters on a WP machine are becoming clogged is to measure the pressure drop across them. A switch or gauge is recommended.

Line 38 "Explosion proof" Some manufacturers have machines certified by a third party National Recognized Testing Laboratory (NRTL), such as Underwriters Laboratories (UL), Canadian Standards Association (CSA), or equivalent internaional body. Applicable to Class 1 Division 1 or Zone 1 machines only. Seldom used for this size range and availability may be limited.

Line 38 "Totally-Enclosed Fan-Cooled (TEFC)" A construction where free exchange of air is prevented between the inside and outside of the motor. The motor is cooled by a shaft-mounted fan external to the main frame or enclosure that forces air past the outside of the frame. Only available in the smaller ratings covered by this specification, normally less than about 800 HP. This is recommended for severe environments. An alternative for larger sizes is the Totally Enclosed Air-to-Air Cooled (TEAAC) type. See below.

Line 38 "Drip Proof Guarded" This is only suitable for indoor applications and will probably give reduced reliability in all applications.

Line 38 "Totally-Enclosed Pipe-Ventilated (TEPV)" There is no free exchange of air between the inside of the motor and the air immediately outside the motor enclosure. Used where the motor is located in very dirty locations or if the motor is installed in a Division 1 hazardous (classified) location. Requires air inlet and outlet ducts to duct air to and from the motor, inlet air filters and usually inlet air blowers.

Line 38 "Other" May include other NEMA or international enclosure designations. It could also designate use of a "Dust-ignition-proof" (DIP) motor for Class II (explosive dust) environments. The DIP motor is totally enclosed and is constructed so that dust does not enter the enclosure. It also prevents heat or sparks inside the enclosure from causing ignition outside the motor.

Line 39 "Totally-Enclosed Air-to-Air Cooled (TEAAC)" Similar in function to the TEFC type. Has an air-to-air heat exchanger, usually mounted on the top of the motor, to remove heat from the internal air of the motor by blowing outside air through the exchanger tubes. Use for locations with severe environments not involving adhering dust. Choose the heat exchanger material based on what is most compatible with air contaminants. Copper-free aluminum is the default and is less expensive than stainless steel. It is often considered for offshore platforms.

D.4.5.1 For the use of enclosures in Classified areas, see NFPA-70 Section 500 or IEC-60079.

D.5 Page 2

Line 4 "Totally-Enclosed Water-Air-Cooled (TEWAC)" Use in environments with adhering dust or dirt, where it is desired to remove the motor-loss heat from a building, or if the motor is critical and none of the other totally-enclosed constructions are applicable. A source of cooling water is needed, usually about 1 GPM for each kilowatt of loss [full load KW × (1.0 – efficiency %/100)]. The material chosen for the cooler tubes is 90/10, copper/nickel.

Line 5 "Redundant Coolers" Redundant Coolers are useful if high availability is required.

Line 5 "Exchanger Location" The heat exchanger is most often mounted on the top of the motor. This reduces the floor space requirements but side mounted coolers reduce the risk of water leakage into the motor, and reduce the overall height.

Line 6 “Cooling Water Conditions” The standard cooling water conditions are listed below and in the standard. If they vary from this, changes to the heat exchanger may be required, therefore the water condition should be listed if different to the standard.

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	≥ 100 psig	≥ 7 bar (ga)
Test pressure (minimum of 1.5 times the maximum allowable working pressure)	≥ 150 psig	≥ 10.5 bar (ga)
Maximum pressure drop	15 psig	1 bar
Maximum inlet temperature	90 °F	32 °C
Maximum outlet temperature	120 °F	49 °C
Maximum temperature rise	30 °F	17 K
Minimum temperature rise	20 °F	11 K
Fouling factor on water side	0.002 hr-ft^2 -°F/Btu	0.35 m^2 $\times$ K/kW

Line 8 “Tube Construction” Single-tube cooler construction usually is specified with drip trays and leak detectors within the motor. "Single tube" means that the motor cooling air is in direct contact with the finned tube through which cooling water flows. When a water leak occurs, the motor must be shut down.

Double-tube cooler construction is warranted for nonspared service. "Double-tube" means that every tube through which water flows is enclosed within a second tube. The clearance between the tubes is small and empties into a separate header. If a water leak should develop in an inner tube, the leak is enclosed in the second, outer tube and collects in the header. This header usually is equipped with a water detector and will trigger an alarm circuit. Both sets of tubes are rated for the operating water pressure, so no leakage occurs in the air path used for the motor cooling. The motor can continue to operate until a shutdown can be scheduled to repair the cooler. The inner tube material is defined in line 4 of page 2; however, the outer tube material is typically copper or a copper alloy.

Line 9 “Flow Sensor” A water flow switch and/or air outlet temperature resistance temperature detector (RTD) is recommended to alarm a loss of cooling water. Normally open or normally closed contacts are dictated by the control scheme.

Line 10 “Air Temperature Sensor” An air temperature sensor is relatively low cost and provides useful data on heat exchanger performance. This should be located in the cold air circuit.

Line 11 “Leak Detection” Leak detection is essential to protect the motor from water leakage. For single tube exchangers the detector is usually in a drip pan above the motor. With double tube exchangers, the detector is in the outer tube header.

Line 13 “Provision for Pre-Start Purging” Specify this for hazardous locations if it is desired to replace all the possibly explosive atmosphere with air from a non hazardous location before starting. It is not practical to provide pre start purging for WP machines and it should not be called for in these cases.

Line 13 “Marine Grade Stainless Steel Fasteners” Recommended for corrosive environments. Common zinc-plated steel fasteners will corrode and make machine disassembly and maintenance difficult. Stainless steel fasteners may cost more, depending on the machine size and the motor manufacturer's pricing policy. There is a risk of stainless fasteners galling and being difficult to remove unless anti seize compound is used.

Line 14 “Degree of Protection IP” “Method of Cooling IC” This refers to the IEC designations for enclosures, which are often used instead of the NEMA designations. NEMA MG-1 compares the two methods.

D.5.1 Mounting

Line 17 “Horizontal, Foot Mounted; Flange Mounted” Most motors are horizontal type. Specify "foot mounted" for most applications. Flange mounted motors are rare in these ratings.

Line 18 “Vertical, Shaft up, Shaft down” Vertical motors are used for in-line process pumps, turbine pumps, etc.

Line 19 “Pedestal” Check if a pedestal style motor is required

Line 19 “Axial Stator Shift Required” Many synchronous motors have their bearings mounted onto "bearing brackets" attached to the motor frame, so axial stator shift is not required. Stator shift is where the stator assembly is axially relocated on the soleplate or base without removing the outboard bearing to expose the rotor poles to facilitate maintenance or removal. It usually applies to engine type motors with only a non-drive-end bearing where the drive-end bearing is integral with the driven equipment. If the motor is to be supplied through a driven-equipment vendor, and you are unsure of a response, indicate a "note" on the data sheet for the driven-equipment vendor to complete this.

Line 20 “Engine Type, Bearings Furnished By ___; Shaft Furnished By __” An engine type motor is typically slow speed and shares at least one of its bearings with the driven compressor. Typically indicate that the driven equipment supplier is to supply the bearings and the shaft.

Line 21 “Baseplate Furnished By”: If a baseplate is furnished, it usually is by the driven-equipment supplier as part of a package. Most motors have soleplates. See below.

Line 21 “Soleplate Furnished By”: Soleplates are steel plates embedded into a concrete foundation onto which the motor is mounted. They are normally furnished by the motor supplier for installation by the purchaser.

Line 22 “Special Connections for Field Piping” Where non-standard piping connections will be used for any water or lube-oil connections, indicate here.

Line 23 “When Rotor Dynamic Analysis is Specified, List of Foundation Data Required from Purchaser” The motor supplier must specifically request the data required so they can perform the analysis. In order for the motor supplier to perform this analysis, dynamic “stiffness” values, or other information may be required. This usually is expressed in kg/cm (lb/in.) for both the horizontal and vertical directions. The foundation designer should be consulted in order to provide this data.

D.5.2 Electrical System

Line 27 “Primary Power Source: Volts, Phase, Hertz” Indicate the nominal voltage, the number of phases, and the power frequency of the electrical system where the motor will be connected.

Line 27–28 “Method of System Grounding, Maximum Ground Fault Amperes” Specify how the power system source to the motor is to be grounded. Most applications are either low-resistance grounded (50 amperes to 400 amperes) or high-resistance grounded (10 amperes maximum). Some systems have “delta” connected transformers at their source with no intentional connection to ground and are “ungrounded.” The method of grounding affects the voltage rating of surge arresters applied to the motor.

Line 29 “Fault Current at Machine Terminals__MVA” Enter the maximum momentary or $^3/_4$ cycle short circuit level (MVA) that can be delivered by the power system. Typically use the maximum expected supply switchgear or circuit breaker duty. This is for determining terminal box pressure release or withstand and coil bracing requirements.

Line 29 “Let-Through Energy__I^2t” If the motor is fed by a fused contactor (less likely with a synchronous motor) enter the maximum let-through energy in ampere squared seconds for the selected fuse that results from the maximum system short circuit capacity.

Line 30 “Minimum Short Circuit MVA at Motor Bus (at __ kV Base), X/R Ratio” Record the minimum short-circuit contribution and X/R ratio from the power system with no short-circuit contribution from other motor sources. This reflects the capacity of the utility company or the generation system and is used to calculate the voltage drop during a start.

Line 31 “Other” This may include details on the electric power system such as "fast-bus transfer" of the supply during power failure or line reclosure during system short circuits which could affect winding mechanical bracing and the shaft design. If the motor is to be fed from an adjustable-frequency drive, include details or references below.

D.5.3 Motor Starting

Line 32 “Across-the-Line Starting at 80 % of Rated Voltage” Applies in most cases. This is where the motor starter or circuit breaker is closed to start the motor with nothing intentionally inserted in the circuit to reduce the voltage to the motor, i.e., full voltage is applied to start the motor. Unless otherwise listed, the motor should be able to accelerate the load with only 80 % voltage at its terminals, to allow for voltage drop in the system feeding it.

Line 33 “Loaded, Unloaded, Partially Loaded, Starting Torques in excess of IEC or NEMA” Pertains to the load imposed by the driven equipment. Most centrifugal-type loads are partially loaded and most reciprocating-type loads unloaded. Data entered for these items must be coordinated with the driven-equipment supplier. Refer to Note 2 in 2.2.5.2 for further discussion. Torques exceeding NEMA MG 1 or IEC are not frequently required unless a very low starting voltage will be used (less than 80 % rated), or if the torque imposed by the load is unusual.

Line 34 “Load Reacceleration Required” If prompt reacceleration of the motor is required following a power failure, indicate "yes". Provide details on the maximum interruption time; the voltage available to accelerate the motor; the driven-equipment speed-torque reference (Is the reacceleration a loaded start due to process upsets?); and any special reacceleration-curve reference such as voltage variation with time due to a generator voltage regulator response

Line 36” Other Starting Method Reduced Voltage Volts” Other starting methods may include captive-transformer (a single transformer feeding only the motor), adjustable-frequency or adjustable-voltage starters, shunt-capacitor (switched during starting), or series-reactor shunt-capacitor starting methods. Where the starting voltage is intentionally reduced by use of an autotransformer, reactor, or resistor, indicate the value of reduced voltage which is provided by the starting method. For example, the voltage would typically be reduced to either 80 % or 65 % with an autotransformer starter.

Line 37 ”Starting Capability Data” Supply the vendor with either the minimum voltage expected at the motor terminals with a certain locked rotor current, or with the minimum available Fault kVA plus the required voltage at the motor terminals. The vendor needs this for motor design.

Line 39 “Number of Full Voltage Starts Required if Not 5000” Most large synchronous motors would not see more than 5000 starts in a lifetime. If the process requires more, list it here. Listing less than 5000 will not save much money and will give an inferior motor.

Line 39 “Consecutive Starts Different from Table 4” The starting capabilities listed in Table 4 are common requirements. The capabilities are based mostly on rotor temperatures. High or low inertia loads as well as the level of loading during starts will affect the practicality of changed starting capabilities.

D.6 Page 3

D.6.1 ASD Conditions

Line 5 “ASD, ASD with DOL Start, Bypass at Utility Frequency” The vendor requires this information for motor design, as there are differences in the motor design when fed from an ASD.

Line 6,7,8 "Torque/Speed/Power information" The motor design, particularly the magnetics and the cooling system are affected by the torque and power versus speed characteristics of the load. The vendor needs this information to properly quote and design the motor.

Line 9 "Other" The type of drive affects the motor design, particularly the winding configuration and the stator insulation. List the type of drive (e.g. LCI, Voltage Source PWM, Current Source PWM, Neutral Point Clamped, etc.)

D.6.2 Bearings

Line 11, 12 "Bearing Type" "Normally check "hydrodynamic" For this size and type of motor, the hydrodynamic ("oil-film") type bearing is most suitable and is the default selection. This contrasts with the antifriction ("ball/roller") type bearing. The motor vendor typically selects the bearing type (Cylindrical, Elliptical, Tilt Pad, etc.) to meet the stiffness and damping requirements of the lateral critical speed study.

Line 11 "Oil Ring Required" Most motors of this size rely on a lubrication system (see below) to move lubricating oil through the bearings. If the power supply to the lubrication skid fails, it is essential to keep oil in the bearings during the motor coastdown. One way to achieve this is with oil rings which take oil from the bearing sump to the bearing itself. Other methods include a "run down tank" or a DC motor driven pump. Most cylindrical sleeve bearing designs permit oil rings, but some others do not. If they can be fitted and if they provide enough oil to prevent high temperatures during coastdown, rings are desirable.

Line 13 "Thrust Bearings, Maximum Connected-Equipment Thrust" Usually leave blank. Applicable only to a motor with a vertically oriented shaft. The driven-equipment supplier would normally enter this data for vertical motors. Both momentary and continuous figures are required for up and down thrust.

Line 15 "Bearing Constant-level Sight Feed Oilers Required" Specify where the motor has self-lubricated bearings.

Line 16 "Special Seals for Gas Purge" Specify for motors that will operate in severe dust or dirt environments. A clean, dry air (or other gas source) must be available.

Line 16 "Non-conducting Seals" Some bearings may require non conducting seals for electrical isolation reasons.

D.6.3 Lubrication System

Many points in this section are determined by the motor vendor, package vendor and purchaser working together.

Line 20 "Self Lube" This is practical for smaller motors where the bearing losses can be dissipated without external heat exchangers.

Line 20 "Pressurized Lube Required" Indicate if a pressurized lube or "flood" lube system is required. This is recommended for all motors rated above approximately 1500 horsepower.

Line 20 "System Supplied By, Common with Driven Equipment" When the driven-equipment has a pressurized-lubrication system, the motor typically is fed from the same system, although shared systems pose a risk of gasses from the driven equipment entering the motor through the lube system. This space is for selecting such a system, designating its supplier, the lubricating oil type, quantity of oil, and the supply pressure. An oil system is typically supplied by the driven-equipment supplier.

Line 21 "Per API 614, (Manufacturer's Standard)" API 614 is a comprehensive, lubrication system specification necessary for applications those type of bearings that cannot be supplied with backup oil rings. This type of system would accompany a compressor and may be common for both the motor and driven-equipment; however, some users prefer to have seperate systems. If an API 614 lubrication system is needed, select either General Purpose or

Special Purpose. Slow Speed or non-critical applications may be suitable for General Purposed and high speed or critical applications will normally require Special Purpose.

Line 21 "Main Oil Pump Required, Integral Shaft Driven, Separate" If an API 614 system is supplied, or if backup oil rings are supplied, a main oil pump driven by the motor shaft is not required. API 614 usually recommends a primary and standby pump which must be designated on the data sheets.

Line 22 "Oil Rings Not Provided" Normally selected, these rings rotate with the shaft to lift oil from a sump onto the shaft journal. The rings provide all the required lubrication for the bearing on smaller motors and emergency backup or rundown capability on large motors. They cannot be applied on elliptical tilt-pad bearings or some ASD motors.

Line 23 "Type/Viscosity of Oil" A typical oil for a common system is ISO Grade 32. The oil system pressure is typically 15-25 psig (100 to 180 kPa).

Line 25 "Oil Mist for Antifriction Bearings" Where antifriction (ball or roller) bearings are utilized, this alternate method of lubrication is not often used, and is user/application specific.

D.6.4 Special Conditions

Line 28 "Shaft and Spider one piece forging for 4 or more poles" A one piece forging is required for 2 pole machines. An integral shaft/spider is recommended for 4 and 6 pole machines.

Line 29 "Special Vibration Requirements" For critical equipment (e.g.: unspared, high inertia load, high speed, or other sensitive applications) lower vibration limits may be specified.

Line 30 "Efficiency Evaluation Factor" See below to determine the "$/kilowatt" to be used for the evaluation of bids based on quoted efficiency. Should be completed for all motors.

Motors should be purchased on the basis of life cycle cost (LCC). LCC is the purchase price of the motor plus the value of losses over the life of the motor using the evaluation factor (EF) and evaluated loss (KWe) shown.

$$LCC = P + EF \times KWe$$

where

P is the purchase price of the motor in dollars;

EF is the EF (\$/kW) = $C \times N \times PWF$;

C is the energy cost in \$/KWH (dollars per kilowatt-hour);

N is the operating time in hours per year;

PWF is the Cumulative Present Worth Factor (this factor typically ranges from 2 to 4 for the purpose of bid valuations);

KWe is the KWe in (kW);

KWe is $L \times HP \times [(100/Eop) - 1] \times 0.746$;

NOTE To convert HP to kW.

L is load factor = (driven load HP)/(motor nameplate HP);

HP is the motor nameplate horsepower;

Eop is the motor efficiency (in %) at the specified driven-equipment shaft load.

Line 31 "National, State/Provincial, Local Codes" List and supply copies of any local, special codes. The copies are required by the API 546 paragraph. For example, southern California installations frequently call for special electrical codes.

Line 32 "External Forces on Motor Housing That May Affect Site Performance" Indicate any forces from piping, ducting, or any auxiliary equipment not provided by the motor supplier. Typically, these loads are insignificant when these items are properly supported.

Line 33 "Special Overspeed Requirement" Machines are normally purchased with the ability to withstand an overspeed specified by NEMA MG-1 (2 min at 20 % overspeed for 1500 rpm and over, 25 % for 1499 rpm and lower) or IEC 60034 (20 % overspeed). These limits are generally satisfactory but for cases such as turbine drive or load overspeed, capabilities beyond the regular limits may be required and should be listed here.

D.6.5 Main Conduit Box

Line 37 "Box Location" Enter which side of the motor the main terminal box is to be mounted with reference to the non-drive end (exciter end) of the motor.

Line 37 "Conductor size, type, insulation and quantity per phase" For the main supply cables to the motor, enter the conductor size, type, insulation as well as the number of cables per phase. A specific catalogue reference for the size and type of cable often eliminates any doubt.

Line 38 "Quick Disconnect Type Bushing Studs or Receptacles" These are rarely specified. Used where a fast change of motors is required in the event of a failure. Specify the type of stud or receptacle.

Line 39 "Space for Termination of Shielded Cables" Terminating shielded cables requires additional space that may require a modification to main terminal box. If shielded cables are utilized select this option and provide specific details to the motor manufacturer.

Line 39 "Cable entering from" Indicate the position of the main supply cable entry to the main terminal box. (Special consideration should be given to motors specified with stator shift—see 2.4.2.16.)

Line 40 "Both Ends of Stator Winding Brought out to Terminal Box" This is common on these machines and is required if differential relaying current transformers are used. It also facilitates insulation testing on individual phases and should usually be specified.

Line 40 "Thermal insulation" This should be considered in locations where moisture condensation on cool metal surfaces is common. It should be specified if no space heaters are provided.

Line 41 "Cable between Stator Windings and Main Terminals" Some users have had problems with the stator winding to terminal box cables failing for various reasons. One remedy to this situation is to use bus and/or extended winding sections for the leads. Each manufacturer has slightly different methods, each with positive and negative features. This point should be discussed if the purchaser has concerns in this area.

Line 42 "Space heaters" Specify heaters in the main terminal box if the unit is to operate in an outdoor or humid environment or when the motor is expected to be unenergized for long periods of time.

Line 42 "Temperature code" This is defined as the maximum temperature permitted at the surface of the heater element, which could be a source of ignition in an explosive atmosphere. For Class I (gas or vapor) Group A, B, C or D locations, specify the Code for the lesser of 200 °C or 80 % of the autoignition temperature from NFPA 497 for the specified gas or vapor involved. The chart below is taken from NFPA 497 and lists liquids with an AIT less than 200 °C.

Table D.1—List of Liquids with an Autoignition Temperature (AIT) of Less than 250 °C, Requiring Space Heaters with Heater Element Surface Temperature Less Than 200 °C (Extracted From NFPA 497-2008)

Material	Group	AIT °C	80 % AIT °C
Acetaldehyde	C	175	140
Acrolein (inhibited)	B(C)	235	188
Allyl Glycidyl Ether	C	57	46
n-Butyraldehyde	C	218	174
Carbon Disulfide	—	90	72
Crotonaldehyde	C	232	186
Cyclohexane	D	245	196
Cyclohexene	D	244	195
Cyclohexanone [a]	D	245	196
Decene [a]	D	235	188
Diethyl Ether	C	160	128
Diethylene Glycol Monobutyl Ether [b]	C	228	182
Diethyl Glycol Monomethyl Ether [b]	C	241	192
Dimethyl Sulfate [b]	D	188	150
1,4-Dioxane	C	180	144
Dipentene [a]	D	237	189
Ethylene Glycol Monobutyl Ether [b]	C	238	190
Ethylene Glycol Monoethyl Ether [a]	C	235	188
2-Ethyl Hexanol [b]	D	231	184
2-Ethylhexaldehyde [a]	C	191	152
Fuel Oils [a]	D	210 to 407	168
n-Heptane, n-Heptene	D	204	163
n-Hexane	D	225	180
Hexenes	D	245	196
Hydrazine [a]	C	230 to 270	—
Isoprene	D	220	176
Iso-octyl Aldehyde [a]	C	197	157
Kerosene [a]	D	210	168
Methyl Formal	C	238	190
2-Methyloctane	D	220	176
3-Methyloctane	D	220	176
4-Methyloctane	D	225	180
Methylal	C	237	190
2-Methyl-1-Propanol	D	223	178
Monomethyl Hydrazine	C	194	155

Table D.1—List of Liquids with an Autoignition Temperature (AIT) of Less than 250 °C, Requiring Space Heaters with Heater Element Surface Temperature Less Than 200 °C (Extracted From NFPA 497-2008) (Continued)

Material	Group	AIT °C	80 % AIT °C
n-Nonane	D	205	164
n-Octane	D	206	165
Octene	D	230	184
n-Pentane	D	243	194
Propionaldehyde	C	207	165
n-Propyl Ether	C	215	172
Propyl Nitrate	B	175	140
Triethylamine	C	249	200
Unsymmetrical Dimethyl Hydrazine	C	249	200
Valeraldehyde	C	222	177

[a] Flash point of these materials is between 100 °F (37.8 °C) and 140 °F (60 °C). Special electrical equipment is required only if these materials are stored or handled above their flash points.
[b] Flash point of these materials is between 140 °F (60 °C) and 200 °F (93.3 °C). Special electrical equipment is required only if these materials are stored or handled above their flash points.

Line 42 "Volts, phase and kW" Due to typical low power requirements (100 – 150 watts) a single phase 120 or 240 volt power supply is selected.

Line 43 "Differential protection current transformers" Recommended for all unspared applications and all motors rated 2,500 HP and larger. There are two current differential protection schemes for motors: phase differential and self-balancing differential protection. Phase differential protection uses six identical current transformers, one pair for each phase. Three of the current transformers are located at the starter or motor switchgear and the other three in the three phases at the motor winding neutral. Self-balancing differential protection uses three zero-sequence, window-type, current transformers installed at the motor terminal box. One current transformer per phase is used with the motor line and neutral leads of one phase passed through it such that the two currents normally cancel each other. The self-balancing scheme is more commonly applied to motors. It usually has a lower primary pickup in amperes and provides motor stator winding phase and ground protection. This scheme does not detect cable faults. The phase differential scheme has the advantage of protecting both the motor stator winding and the motor feeder cables in the differential protection zone. However, this arrangement can be prone to unbalancing of signals and nuisance tripping due to instrument wire failure. Appropriate protective relays must be provided in the motor starter or switchgear. Core-balance, or window type, current transformers are the most common. Either specify the specific type (e.g. type BYZ) or the current transformer accuracy class. A "C 10" accuracy class is usually adequate, but "C 20" may be required depending on the protective relay type. Recommend a "C 10 accuracy class" for "type" and a ratio of 50 to 5 (50:5) for self-balancing. Since phase differential current transformers carry load current, they must have primary current ratings chosen accordingly. Bar-type current transformers are only applied for very high continuous current ratings, and are specified with appropriately high ratios and accuracy classes to match a set of three current transformers in the supply switchgear. Specify who will supply and who will mount the current transformers. (For phase differential systems it may be advisable to have all six current transformers purchased with the switchgear and three supplied to the motor manufacturer to ensure all six are matched correctly.)

D.7 Page 4

Line 4 "Surge capacitors" Are connected between each phase and ground to decrease the slope of the wavefront of lightning surge voltages and switching surge voltages. Recommended for unspared motors, those connected through one transformer or directly to a bare overhead line, or those which have switched capacitors on the same voltage level. Specify 0.5 microfarad for motor voltage ratings through 4160 volts and 0.25 microfarad for ratings 6600 volts and above. Surge capacitors may or may not be used in conjunction with surge (lightning) arresters. Specify who will supply and who will mount the surge capacitors.

Line 5 "Surge arresters" Are installed one per phase connected between the phase and ground, to limit the voltage to ground impressed upon the motor stator winding due to lightning surges. Recommended for the same conditions given for surge capacitors. For those motors connected to a bare overhead line through at least one transformer (protected on its primary with arresters), one set of surge arresters applied on the main switchgear to protect a group of motors is usually adequate. Specify 2.7 kV rated arresters for 2.3 kV rated motors, 4.5 kV for 4.16 kV motors, 7.5 kV for 6.6 kV motors, and 15.0 kV for 13.8 kV motors. The arrester voltage ratings are usually adequate if a ground fault will be cleared in one second, that is, low resistance grounded systems. However for high resistance grounded systems where fault clearing is not immediate, the arrester MCOV rating must be greater than the system line to line voltage. This would mean 3 kV arresters for 2.3 kV motors and 5.1 kV or 6 kV arresters for 4.16 kV motors. Specify who will supply and who will mount the surge arresters.

Line 6 "Current transformers for ammeter" If a single current transformer is needed for load-current indication local to the motor, specify the type (usually a window type) and ratio with a maximum current rating of 150 % of the rated-load current of the motor. An alternative is to use a current transducer mounted in the switchgear wired to an ammeter mounted at the motor.

Line 8 "Potential transformers for voltmeter" Rarely specified, except on some captive transformer applications where there may be no switchgear available at the motor utilization voltage to extract a voltage. (Adds complication, space requirements, and a potential failure point within the terminal box.) If required, include details on who is to mount them, the quantity, the ration and the accuracy class. Also specify if fuses are required. If the area is classified, most applications of fuses within the terminal box necessitate purging the terminal box

Line 10 "Provisions for Purging" Purging is required by the *National Electrical Code* for terminal boxes having surge arresters mounted within the terminal box when the motor is installed in a Class I, Division 1 or Zone 1 area. Specify for this condition.

Line 11 "Removable links" Recommended for motors with larger terminal boxes to permit isolation of each phase of the motor from the incoming cable and surge protection. This permits maintenance high-potential or insulation tests to be done without needing to remove stress cones and disconnection of devices in order to isolate the motor windings.

Line 11 "Silver- or Tin-Plated Bus Joints" Recommended for bus links and cable terminations to reduce contact resistance from corrosion. Tin is recommended for locations where sulfur is present.

Line 11 "Ground bus" Should be specified for all motors.

Line 12 "Insulated Terminations and Interior Jumpers" The risk of a phase to phase or a phase to ground fault is reduced if the internal conductors are insulated. This should be specified in most cases.

D.7.1 Accessories

Line 14 "Frame space heaters" All motors should include space heaters. Normally, the "manufacturer's standard" bar type heater sheath material is acceptable, but stainless steel or other material could be specified. Flexible belt type space heaters should be avoided, and any type of heater that contacts the surface of the motor winding is not acceptable. Specify 120 volt or 240 volt, single-phase or 208 volt or 480 volt, three-phase power, depending on what power source would be available with the motor shut down. Temperature Code is defined by the maximum temperature permitted at the surface of the heater element, which could be a source of ignition in an explosive atmosphere if the element is too hot. For Class I (gas or vapor) Group A, B, C or D locations, specify the Code for the lesser of 200°C or 80 % of the autoignition temperature from NFPA 497 for the specified gas or vapor involved.

Line 15 "Bearing heaters" Not specified very often, because most motors in extremely cold climates are installed in heated shelters. Where needed to bring lube-oil in the bearing housing sump up to the minimum temperature recommended by the manufacturer, specify a type that can conform with API 546 specifications. If an electric immersion heater is used, it shall have a maximum watt density of 2.3 watts per cm^2 (15 watts per $in.^2$) to avoid carbonizing the oil.

Line 16 "Exciter Space Heaters" Normally specify as for frame space heaters.

Line 17 "Winding temperature detectors" These detectors are installed in intimate contact with the winding insulation and give an accurate measurement of the operating temperature of the winding. They provide better protection for the motor than current-sensitive overload relays. They also improve protection against clogged air filters which can cause high winding temperatures in weather protected (WPI and WPII) enclosures. Generally recommended on all motors covered by this Standard. Three detectors per phase are the default, allowing two for motor protection and one for other monitoring or spare. Temperature detector type should be specified, depending on the monitoring system design. Typical resistance temperature detectors (RTDs) are 100 Ω at 0 °C, platinum, 3 wire, with a temperature coefficient of resistance (TCR, Ω/Ω °C) of 0.00385 per EN 60751, Class B. Other types are 120 Ω at 0 °C Nickel 2 wire and 10 Ω at 25 °C Copper 3 wire. The need to ground one lead is dependant upon the instrumentation requirements. Typically one lead is grounded at the motor.

Line 18, 19 "Other Detector, Thermocouples" Other means of detecting overtemperature or measuring winding temperature such as non linear resistors or thermocouples are available but are more often used in smaller machines.

Line 21 "Monitor for Shaft Grounding Brush Replacement" Some machines are supplied with a shaft grounding brush to keep shaft voltage down. If the brush wears out the shaft may build up voltage, causing a hazard. Monitoring systems are available to annunciate the need for brush replacement and should be specified if shaft voltage buildup is a concern.

Line 22 "Test Device for Rotating Electronic Components" Systems are available which can be easily connected to the motor and are able to assist with troubleshooting the rotating electronic components. The availability and features should be discussed with vendors.

Line 22 "Rotating Diode Failure Detection" Exciter rotating diode failure can be detected by stationary devices which monitor the waveform of the exciter current. This feature can be useful in analyzing failures and annunciating problems.

Line 23 "Online Rotor Monitoring System" Systems are available which can give data on machine rotor winding resistances, temperatures etc. as well as detect ground faults. The availability and features should be discussed with vendors.

Line 24 "Exciter Power Supply" A reliable power supply for the exciter is essential for operation through brief dips in power system voltage. Possible sources are a Permanent Magnet Generator (PMG) which is more common with alternator excitation than motor's, a constant voltage transformer (CVT) which gives a constant output for a range of input volts, a phase controlled rectifier which is essentially oversized for the application, or feeding the exciter power from an uninterruptible power supply (UPS). Choose the most practical for the application.

Line 26 "Auxiliary Equipment Enclosures" List the auxiliary equipment location as determined by the equipment layout.

Line 28-35 "Hydrodynamic or Thrust Bearing Temperature Devices" These detectors should be applied consistent with the entire equipment train. They usually are applicable to large (1000 HP and greater) and special-purpose equipment trains. They can provide early warning of lube-oil loss or impending bearing failure. API 670 outlines requirements that assure accurate bearing-metal temperature measurement. When radial temperature detectors are used for shutdown systems, either resistance temperature detectors (type 100-ohm platinum at 0 °C or 120-ohm nickel at 0 °C) or thermocouples [iron constantin (Type J), for example] can be specified. Separate terminal heads usually are specified, and the external conduit is run to each head.

Line 29 “Provisions Only, API 670, Other” Where future capability for installation of sensors or use of sensors during factory tests is desired, specify "provisions only." A "manufacturer's standard" installation may not represent the true bearing metal temperature since motor manufacturers often monitor the bearing shell temperature, an inch or more from the shaft-bearing interface. If bearing temperature monitoring is specified, “API 670” requirements are recommended since the temperature-sensing tip location is defined at the most representative place on the bearing.

Line 30 “RTD: Type” Specify either 100-ohm platinum or 120-ohm nickel where an RTD is desired.

Line 30 “Thermocouple: Type” Iron constantin (Type J)can be specified, for example, where a thermocouple is desired.

Line 32 “Dial-Type Thermometer, Alarm Contacts” Only applied to nonpressure-fed bearings. Specify where an indication of the oil temperature is desired. If alarm contacts are required for annunciation, indicate "yes" and the type and number of contacts under "alarm contacts."

Line 33 “Location of Bearing Temperature Sensor Wire Terminations” Indicate the location of the detector terminations. Often, separate terminal heads are supplied and the external conduit is run to each head. The detector terminations could also be enclosed in the same terminal box as the winding RTDs.

Line 34, 35 “Recommended Settings” Normal alarm temperature is 80 °C. If applicable, normal shutdown temperature is approximately 100 °C. Machine vendor will supply recommendations.

Line 36 to 43 “Vibration Detectors” Specify consistent with the equipment train. For motors operating at 1,200 rpm and higher, two probes per bearing and a phase reference probe should be specified (for slower speed motors, consideration should be given to bearing housing seismic sensors—see line 43). Two externally adjustable probes per bearing are normal (90 degrees apart), but four probes per bearing may be desired if the probes are not accessible during the motor operation and vibration monitoring is considered important (usually only two oscillator/ demodulators are supplied for each bearing, since the probe wires can be exchanged during operation).

Certain slow speed applications (e.g., reciprocating compressor motors) often make use of a phase reference probe without the need for any proximity-type vibration probes.

Line 44- “Bearing housing seismic sensors” Specify consistent with the equipment train. Often applied on motors with eight or more poles. Accelerometers should be specified using API 678, or velocity pickups may be specified. Specify acceleration, velocity, or displacement transducer output for accelerometers (recommended is velocity output); velocity or displacement transducer output for velocity pickups. Spot-faced surfaces can be specified for future mounting of transducers. Specify the location of the sensors—”H” horizontal, “V” vertical and/or “A” axial.

D.8 Page 5

Line 6 “Vibration Switch” These devices are not normally recommended for motors of the size range covered by this specification, since they offer less protection than API 670 or API 678 systems.

Line 8 “Alarm and control switches” If the control scheme that senses such things as pressure drop across filters, and temperature switch operation uses DC, the switch contacts should be rated for DC.

Line 9 “Partial discharge detectors” Partial discharge levels and phase relationships can be used to assist in the predicting of motor insulation failure. This has proven to be quite effective for systems above 4160 Volts. With systems rated 4160 Volts and lower, partial discharge monitoring and analysis gives a shorter warning time than when used for higher voltage systems. Various sensor types are used, and the desired type should be specified. Partial discharge monitoring has not proven to be useful with motors driven by medium voltage AFDs.

Line 11 "Separately Powered Auxiliary Fan(s)—Driver Information" Some types of enclosure use separately powered fans to move air through the motor. The motors and fans should be reliable. Auxillary powered device motors shall be per IEEE 841.

D.8.1 Controls

Line 17 "Motor Vendor to Furnish" This section lists the control and excitation requirements.

Line 18 – 19 "Motor Vendor to Furnish" "Manufacturer's Standard Excitation Control Including Application & Protection) Package for Mounting in" The excitation control can be supplied by most vendors as a single standard unit, instead of a number of separate devices that are then mounted individually. It is usually simpler to purchase the single standard unit if the system excitation and control requirements can be met by that unit. Whether it is mounted in the main switchgear or in a separate panel depends on user preference and available space.

Line 20 – 21 "Separate Control Devices, as Checked, for Mounting in" This allows users to check off particular devices and meters instead of buying a standard package. Most standard packages have the devices listed here, except for vibration monitoring and devices usually associated with motor protection such as overload, temperature and differential protection. Where practical, the standard package is recommended.

Line 22 – Line 11 Page 6 "Completely Assembled Panel with Devices as Checked, Separate Devices as Indicated" In some cases, where particular requirements exist, specify this. These devices are then usually mounted in space provided in a separately purchased switchgear or sometimes in a panel provided by the motor vendor, as specified.

The trend is to as much metering as possible (due to the relatively low cost of metering) and the ability to control excitation to give controllable power factor or VAR output. It has also been found desirable to feed the exciter power from either a UPS or CVT, to improve the ride through during voltage dips.

D.9 Page 6

D.9.1 Driven Equipment Information

Line 13 "Driven Equipment Tag No" Enter identification number description and location of driven equipment.

Line 14 "Type" Enter the specific type of driven equipment.

Line 15 "Reciprocating Compressor: Compressor Factor, `C'"Usually completed by the compressor supplier. This factor reflects how much motor WK^2 is required to limit the line-current pulsations to within the NEMA limit of 66 % of motor full-load current, unless a lower limit (40 % or 20 %) is specified. See NEMA MG 1 for details.

Line 16 "Max Current Pulsation" The amount of AC line current pulsation desired is indicated here. The NEMA standard is 66 %, but can be reduced through higher rotor or additional flywheel inertia. In many instances, 40 %, or less is specified to reduce light flicker on power systems with weak short circuit capacity.

Line 17 "Calculated Efficiency Based on Current-Pulsation Operating Condition" Specify for reciprocating loads if the motor vendor is expected to calculate the motor efficiency by taking the current pulsations in to account.

Line 18 "Driven Equipment Mfr." Enter the name of the driven equipment manufacturer. **"Type/Model"** —Enter the specific type or model number of driven. **"RPM"**—Enter the rated speed of the driven equipment. This will be different from the motor speed if a gearbox is being used.

Line 19 "Load Speed-Torque Curve No." The driven equipment manufacturer usually supplies this. If the motor is being purchased directly, this is a curve reference for the speed versus torque of the driven equipment under the most stringent starting conditions. Fill in the load curve details of the driven equipment including as a minimum the load torque during acceleration at zero, half and full speed. List or check off what type of equipment it will be driving. For driven equipment, indicate whether the start is loaded or unloaded (i.e., with valves, dampers, or guide vanes closed). **"Crank-Effort Data"**—This is a compressor-supplier document that reflects how the torque varies with each revolution of a reciprocating compressor for a specific operating condition.

Line 20 "Total Driven-Equipment GD^2/WK^2" List the load inertia including all parts such as couplings, gears, and driven-equipment rotors. These usually are referenced to the motor speed. The referenced speed should be indicated regardless of which one is used.

Line 21 "Driver Connection to Load" Check one of the following:

"Direct Connected" Check, if the motor is directly coupled (at the same speed) to the driven load (i.e. not coupled through gears, belts, etc.).

"V-Belt Connected" Check if the motor is belt connected.

"Gearbox" Check, if applicable.

Line 22 "Speed Increasing—Reducing Gear" List the ratio of speed.

Line 23 "Motor Shaft Extension" The motor shaft extension may be cylindrical, tapered or flanged. The type is determined by the coupling that is specified.

Line 24 "Rotation of Motor Viewed from Non Drive End of Motor" Indicate the direction of rotation as viewed from the exciter end (the "outboard" end) of the motor. Indicate clockwise, counterclockwise, or bi-directional.

NOTE The direction of rotation of some units must be designed and manufactured accordingly, and cannot be changed in the field without major consequences.

Line 25 "Coupling" Enter "gear," "diaphragm," "resilient," etc., as appropriate. Include the coupling manufacturer and model number.

Line 26 "Manufacturer's Standard/API 671" Decisions on couplings are typically joint efforts between the purchaser and driven equipment vendor.

Line 27 "Coupling GD^2/WK^2" Enter the rotational inertia of the coupling at a specified RPM, usually the motor speed.

Line 28 "Supplied By" Most often, the driven-equipment supplier provides the coupling, unless the purchaser is coordinating the interfaces between equipment.

Line 29 "Mounted By" Most motors ordered through a driven-equipment manufacturer have their coupling-mounted by the manufacturer. Motors rated 1500 rpm and greater usually undergo a rotor dynamics test and requires that the coupling be mounted by the motor manufacturer. Coordination is required at the time of order entry to assure the coupling half, with its idling adapter which allows the motor to be run uncoupled, is properly coordinated. For example: The coordination may involve special tapped-hole patterns on the idler plate for adaptation to a balancing machine drive.

D.9.2 Miscellaneous

Line 32 "Painting" The standard painting is normally accepted unless the motor is to be installed in a severe environment, such as offshore. If special paint is specified, include the surface preparation and paint specifications with the quotation request to the manufacturer. Consideration should be given to the painting system used on the inside surfaces of a WP enclosure.

Line 32 "Special Weather Protection" List any special needs here.

Line 33 "Proof of Nonsparking, Corrosion-Resistant Fan" This is usually only specified for motors rated for speeds of 1800 rpm and higher.

Line 33 "Quantity of Special Tools Required" The manufacturer should indicate here that non-commercially available tools are required for the assembly or maintenance of the machine. Normally, one set is adequate.

Line 34 "List of Special Low-Temperature Materials Requirements" This section applies to operating temperatures less than –20 °F (–29 °C). At low temperatures many steels become brittle. Alloys that remain ductile at the minimum operating temperature shall be used.

Where motors are operating in temperatures of –20 °C or lower, it is necessary to ensure that steel components operating under stress are made of an alloy that is capable of maintaining its mechanical properties at reduced temperature.

Line 35 "Special Winterizing Requirements" Specified where winter conditions exist prior to start-up. This is specified so the motor supplier can identify protective items and identify the items that they will furnish.

Line 36 "Materials to be Identified With Applicable ANSI, ASTM, or ASME Numbers" If certain parts identified by standard designations are required, list them here. This may include flanges, minor hardware, shaft material, bearing babbitt alloy, etc.

Line 37 "Typical Drawings and Literature with Proposal" Indicate when the purchaser requires typical drawings and assembly instructions included with the proposal.

"Electronic Instruction Manuals" Indicate here if the purchaser requires instruction manuals to be provided in electronic format.

"Photos Showing Assembly Steps Required" Indicate here if the purchaser requires photos showing the step by step assembly of the machine or components such as bearings.

Line 38 "Performance Curves Supplied in Digital Format" Some power system analysis software can accept motor data directly, without having to key in the data. Specify the required format here.

Line 39 "Manufacturer to Supply Curve in Tabular Format" If keying in the motor data is desired, check this box.

Line 39 "NRTL Certification, PMI Certification" If documentation is required to have certification from a NRTL or to have Positive Material Identification, list here.

Line 40 "Detailed instructions and photographs for disassembly and inspection" For machines that have unusual features, or if the maintenance people are not familiar with large machines, it may be helpful in the future to have photographs detailing its arrangements.

Line 41 "Type Tests and Design Information Verifying all Gasket Materials are Impervious to Lube Oil and Chemicals" If there are concerns about lube oil or chemical attack on gasket material, specify this information be supplied.

Line 42 "Special Identification for Transmittals" Any special identification for drawings, correspondence, etc. should be entered here.

Line 42 "Separate Nameplate with Purchaser's Information" If a special nameplate is needed for identifying the equipment number or other information, detail the requirements here.

D.10 Page 7

D.10.1 “Shipment”

Line 4 “Domestic” Depending on the protection inherently offered by the enclosure, specifying this would include the protection described in API 546 and coverage of the motor by a tarpaulin or plastic. Specifying Export gives heavier packaging.

“Export Boxing Required” Would normally include complete, sealed coverage with desiccant and a substantial box is built around the motor. The manufacturer should describe the preparation included when the proposal is presented.

“Commissioning Assistance Required” Indicate here if the purchaser wants the manufacturer to provide assistance during field assembly or commissioning. There is an additional free charged for this type of service typically quoted on a daily rate.

“Mounted on Skid” The motor is normally mounted on a rigid skid as a base for shipping.

Line 5 “Special Shipping Bearings” These are specified to prevent damage to the normal running bearings due to abnormal handling during shipment, such as impact, dropping and railyard humping. Normal handling during shipment does not usually affect the bearings, so it can be considered an “insurance policy” for motors in which timely start-up is necessary. Shipping bearings alone, however, does not prevent damage to other parts from this type of abuse. Critical shipment should include “g” (acceleration) recorders to monitor handling.

Line 5 “Outdoor Storage for More Than Six Months” Indicate if this is to be the case. Special storage provisions may be recommended by the motor supplier.

Line 5 “Piping Assembled” Specified where coolers or lube-oil piping are to be supplied by the motor supplier.

Line 6 “Electronic Vibration Test Data” An electronic copy of the vibration test data may be useful for future reference. A format that will be usable in future years should be mutually agreed upon.

D.10.2 Motor Data

This data, plus that on Pages 8 and 9 is to be filled in by the motor vendor with the proposal or after the order.

D.11 Page 8

Line 9 “Provide Motor Preliminary Parameters with Proposal” The basic rating data listed here is necessary for preliminary power system calculations. Since these preliminary calculations are normally required, they are normally necessary.

D.12 Page 10

D.12.1 Analysis, Shop Inspection, and Tests

Line 7 “Acceptance Criteria” This section of the data sheet is used to indicate the analyses, inspections, and testing that are required during the manufacturing, assembly, and final testing of the machine. The number of procedures that are required may have a significant impact on the price and quality of the final machine. Required tests may be “witnessed" or “observed." For a definition of these terms, refer to API 546, 4.1.3.

Line 8 “Coordination Meeting” A coordination meeting is useful at the start of the project to ensure that the vendors understand the scope and intent of the project, and that the motor vendor knows what will be required of the motor. In addition, the purchaser will learn of any general vendor concerns about the application.

Line 9 "Design Review" This is a comprehensive review meeting where the detailed electrical and mechanical designs are discussed and any electrical/mechanical analyses are presented. This is recommended for critical motor/driven equipment trains, ratings above 3000 HP, or for new manufacturer designs (prototypes). This meeting is not the order coordination meeting. The purchaser and vendor representatives meet after preliminary engineering is complete (normally 4 to 6 weeks after placement of order) to review designs and coordination with other associated equipment. The review includes but is not necessarily limited to the following topics:

a) performance curves;

b) acceleration times;

c) allowable stall times and temperatures of rotor parts;

d) method of efficiency determination and guarantee of efficiency;

e) current pulsations for reciprocating loads;

f) number of starts allowed;

g) inertia of the machine and coupled equipment;

h) stator winding and winding insulation system;

i) rotor winding, mechanical design, fits, construction, balance;

j) shaft design stress, short circuit torques;

k) torsional and lateral critical speed analysis and rotor sensitivity analysis (response to an intentional unbalance);

l) foundation and base stiffness;

m) coupling type and coordination;

n) bearing details;

o) bearing and coupling insulation;

p) lubricating oil type and oil inlet temperature range;

q) API 546 compliance;

r) "Witness" and "Observe" points for inspections and tests;

s) test agenda; and

t) data for performance of electrical power system studies by the purchaser.

Topics may be added and subtracted as needed.

Line 10 "Torsional Analysis" This is normally done by the driven-equipment manufacturer, but could also be verified by the motor manufacturer or a third party.

Line 11 "Lateral Critical Speed Analysis" This analysis is usually done by the motor manufacturer and gives the system "critical speeds" of the rotor, bearing, bearing support, and foundation system. A critical speed is usually excited by rotor unbalances or misalignment. It is important to predict where the critical speeds are and how the rotor will react to excitations that can result in lateral shaft vibration. This analysis is recommended for two-pole motors 800 HP and larger, or for four-pole motors 5000 HP or larger, unless the motor is specifically designed to operate below its first system resonance. Most other ratings operate well below the first critical speed.

Line 12 "Review of Quality Control Program" This would normally be specified when a new supplier has been specified and the purchaser would like to review documentation of the vendor's quality assurance program.

Line 13 "Submit Test Procedures 6 Weeks before Tests" This is specified when the purchaser wants time to review the proposed test routine and clarify what is to be done.

Line 14 "Inspection for Cleanliness per API 614" Requires the lube-oil system cleanliness of API 614. Specify when the special-purpose API 614 lube-oil system is specified for the drive train.

Line 15 "Observance of Assembly/Dismantling" Specify if the purchaser wishes to reserve the right to observe the testing, dismantling, inspection and reassembly of the motor.

Line 16 "Demonstrate Accuracy of Test Equipment" The motor supplier should have this documented every 6 months to 1 year and should be able to supply this documentation on request. If the test setup is unique or if the motor supplier does not have the accuracy documented, you may wish to specify this.

Line 17 "Stator Core Test" A quality test for core plate insulation integrity or damage. Some suppliers do this test during manufacturing, but should only be specified by the user for unspared machines or applications where the machine will be inaccessible for easy repair or replacement.

Line 18 "Surge Comparison Test" This is recommended. The risk of not doing the test is that marginal turn-to-turn insulation in the winding may not fail during the running tests but may fail in operation when subjected to mild power system surges. The test voltage should be agreed upon with the vendor, as too high a test voltage may induce premature failure.

Line 19 "Special Surge Test of Coils" Recommended for windings rated 6600 V and above, usually as an "observe."

Line 20 "Sacrificial Coils Cut Into Segments" The sacrificial coils made for the special surge test can be cut into segments after the surge test so that they may be inspected for voids in the insulation. Machines with terminal voltages over 4160 Volts are subject to partial discharge deterioration if there are excessive void numbers or dimensions. The acceptability criteria are difficult to define but should be worked out before the tests. Segments should be examined from both the slot (straight) section and the end turn section.

Line 22 "Partial Discharge Test" A way to detect possible future partial discharge problems with insulation is to perform an off line partial discharge test on the motors in the factory. Amplitudes and phase relationships can be used to find where the possible problems exist. Acceptable levels vary between systems and should be derived in discussion with the vendor. Significant deviation between phases, or between similar machines, should be investigated. System partial discharge performance often improves in the first few months of operation.

Line 23 "Balance in a Minimum of 3 Planes" Recommended for machines operating in the flexible shaft mode.

Line 24 "Dynamic Balance Rotors 600 rpm and Above" This is a relatively low cost option and will give improved long term performance. It is recommended and is the default selection.

Line 25 "Final Balance" A final balance is required if the rotor has not been component balanced.

Line 26 "Component Balance > 4-Pole" Specify this on slower speed machines only if vibration is expected to be a concern. 2-pole and 4-pole motors are required to be component balanced, meaning the basic rotor and shaft assembly is first balanced, then as components such as fans are added, and further balance correction is only to be performed on that component. This only adds correction where the unbalance is located, and makes rebalancing simpler.

Line 27 "Residual Unbalance Verification Test" This balance verification procedure is recommended for motors with 2 or 4 poles, and for six pole motors above 3000 HP. This test is not necessary for motors having eight poles or more.

Line 28 "Balance Check with Half-coupling" Usually warranted only for two-pole motors of large size (2000 HP and above) to determine the effects of mounting the coupling on the balance of the rotor. This is done in the same time frame and using the same procedures as the residual unbalance test. Check "required" when this is to be done.

Line 29 "Running Tests with Coupling Half" This is recommended for all 2-pole motors and those 4-pole motors operating above their first critical speed.

Line 30 "Stator Inspection Prior to Vacuum Pressure Impregnation" This is a physical inspection of the iron core of the motor and the winding insulation taping before the winding is put through vacuum pressure impregnation (VPI), a procedure to seal and solidify the winding insulation system. This inspection should be specified for very critical, unspared motors or for motors with voltage ratings 6600 V and above. Since this is a qualitative inspection it should be "witnessed," when specified.

Line 31 "Sealed Winding Conformance" This test involves submersing the motor winding or spraying it with a wetting solution to verify the seal of the insulation system. This test may be applied to critical, special-purpose motors, those whose windings will be exposed to weather or wash down conditions and when purchasing from an unfamiliar supplier. This test should be as a "witness," because corrective measures, in the event of a failure, require purchaser involvement.

Line 32 "Power Factor Tip-up Test" Recommended for stator voltages 6600 V and above for the completed stator. This test provides a "base line" for later maintenance tests to detect corona discharge within the insulation system. This test may also be specified on sacrificial coils for development testing, but acceptance criteria needs to be agreed upon between the user and supplier. The power factor tip up test is usually conducted at 10 % and 110 % or 20 % and 120 % of rated line-to-ground power voltage. The test results are plotted for each motor and percent deviation is calculated. When multiple motors of the same design are tested and compared, the test values should be similar. Any motor that deviates significantly from the others should be investigated further for any potential winding/insulation problem(s).

Line 33 "Manufacturer's Routine Test" This is the test that the manufacturer does as a minimum, to meet the NEMA or equivalent requirements. This will usually be done as part of the more extensive tests.

Line 34 "Insulation Resistance Test Using Table 7 Values" These voltage levels are recommended.

Line 35 "Bearing Dimensional and Alignment Checks before Tests" This is recommended for all motors. Records are made of bearing fits and clearances. In addition, a bearing disassembly and inspection is required at the completion of the running tests.

Line 36 "Bearing Dimensional and Alignment Checks after Tests" This item supplements the normal bearing inspection of 4.3.2.1.j and is recommended for two pole motors operating above their first mechanical-system resonance ("critical speed") to assure the bearings have had no distress as the rotor speed passed through the resonance. Also recommended for motor designs where the mechanical performance is sensitive to small changes in bearing clearances.

Line 37 "Vibration Monitoring and Recording" Evaluate the vendor's proposed data-acquisition system for vibration tests. Very useful and should be used for motors which will undergo unbalance-response tests. This requirement primarily applies to two-pole motors 1000 HP and above, but may also be applicable to slower-speed motors of ratings above 3000 HP. This is standard practice for many manufacturers. Use of a recording system actually saves the manufacturer test-floor time, since an unbalanced-response test, which takes up to 30 min for each “coast down," need only be done once and the data accessed rather than being done four times (once for each shaft vibration probe).

Lines 38 – 45“Complete Test” Imposes the API 546 “Complete Test" requirements, which are common for large or critical service machines and two-pole units. Specify this when the efficiency and temperature rise is to be determined. This test should be specified for at least one (generally the first) of each motor rating when multiple units are ordered at the same time. It should also be specified where the EF justifies the test cost to prove the efficiency.

Line 45 “Sound Pressure Level Test” This test should be done to establish a base line and to assist in solving problems for any noise sensitive situations.

D.13 Page 11

Line 8 “DC High-Potential Test” The motor will already have had a final AC high-potential test for a one minute duration to prove the insulation of the motor. Subsequent high-potential tests in the field will most likely be DC tests. If a base-line DC test is desired to compare with tests in the field, specify here. This test is performed at approximately 75 % of the equivalent final AC high-potential test, so it does relatively little damage to the insulation at this stress level.

Line 9 “Torque Pulsations During Starting” Synchronous motors generate significant oscillatory torque during starting, which can excite torsional resonances and cause fatigue failures. Manufacturers have methods of predicting these torques and the actual levels can be verified by tests. This is recommended for the first (type) test of a design where the analysis indicates there may be a concern. The data is useful for all motors where there are torsional concerns.

Lines 10 – 11 “Rated Rotor Temperature Vibration Test” Specify this if the motor is not going to have a complete API test but it is still important to know that it is thermally stable.

Line 12 “Unbalance Response Test” Recommended for all two-pole motors 1000 HP and larger and all four-pole motors 5000 HP and larger to verify the motor’s performance operating through its first resonant speed, or to verify the location of its resonant speed above operating speed. This may be especially useful for motors intended for variable speed operation or those that will see frequent starting operations.

Line 13 “Bearing Housing Natural Frequency Test” Normally specified for the first motor manufactured of a certain frame size, or a uniquely designed motor. The risk of not requiring the test is low due to the low bearing housing vibration limits required by API 546, and if the motor passes the vibration tests, the motor probably does not have a significant resonance.

Line 14 “Certification of Materials” Upon request the vendor shall provide certification of material such as mill reports for major castings, forgings, and shaft material.

Line 15 “Final Assembly Running Clearances” This is recommended for critical motors.

Lines 16 – 21 “Material Inspection” A list must be attached which specifies the parts to be examined and the types of examinations to be done. For important motors the following material inspections are typical.

a) Welded Shafts—liquid penetrant, magnetic particle, hardness.

b) Forged Shafts—ultrasonic inspection.

c) Welded Fans—liquid penetrant and magnetic particle.

d) Cast Fans—radiography.

e) Bearing Babbitt—ultrasonic.

f) Lifting lugs—liquid penetrant and magnetic particle.

Line 22 “Certified Data Prior to Shipment” Specified for critical machines when the test data must be submitted by the vendor and reviewed prior to shipment.

Line 23 “Burn-in Testing of Rotating Element Mounted Electronic Components” To improve the reliability of the excitation system rotating electronics a burn in test can be done to reduce the risk of “infant mortality" or inadequately designed systems causing premature excitation failures.

Line 24 “Heat Exchanger Performance Verification” This test confirms that water to air, or air to air heat exchanger has sufficient capacity to cool the air entering the motor. An inadequate heat exchanger will restrict the performance of the motor. Details of the test should be worked out between the parties involved.

Line 25 “Pulsating Torque Tests for 4 and 6 Pole Machines” The data described in Line 9 is of particular importance to large 4 and 6 pole machines, where torsional oscillations are particularly significant. Specify whenever the drive train is complex or where torsional concerns are apparent.

Line 26 “Other” Examples of other analysis, inspection, or tests that might be specified are as follows.

(Analysis)—Indicate other analyses to be done by the motor or driven-equipment manufacturer, such as current pulsation analysis for reciprocating loads.

(Tests)—These tests are normally “witnessed" if done at the same time as other tests. Specify as applicable:

a) “Cooler Hydrotest”—Applies 150 % design pressure to the cooler to make sure it does not leak. Only specify for motors with water coolers (TEWAC). Usually specified as “required” or “observed” with the test done at the cooler manufacturing site.

b) “Leak detector”—Verifies the detector works when water is present. A simple test to be specified for TEWAC motors only.

c) “Air Filter DP Switch”—This test for proper operation of the air filter differential-pressure (DP) switch should be made when the DP switch is specified on weather protected motors.

d) “Reed Critical Frequency”—Only applicable to vertical motors A test to verify the mechanical resonance of the motor structure, which acts as a vibrating “reed." A test in the motor manufacturer’s factory only confirms the calculated value for the motor by itself. Considering the expense of this test, it is not specified often. It is a more meaningful test if the motor is mounted to the actual pump head and the test performed on the assembled motor and pump in the pump manufacturer’s shop. Reed resonances should be at least 15 % separated from running-speed frequency excitation for the assembled motor and pump.

e) “Inspection of Equipment Lube-oil Piping”—Applied when a motor with a forced-lubrication system has a thorough inspection program. Recommended for forced lubricated bearings where a thorough flush of the equipment lube-oil piping will not be made at the installation site.

Annex E

Generator Data Sheet Guide

The material in this annex offers a guide to the information on the data sheets in Annex B.

E.1 Purpose

This data sheet guide provides instructions for completing the API Synchronous Generator Data Sheet before obtaining bids. It also contains information to help evaluate data supplied by the vendor. This data sheet guide presumes the specifying engineer:

a) Is familiar with the process of procuring generation equipment. If not, the specifying engineer should refer to the Specifying and Purchasing Procedure section of this manual.

b) Is familiar with the purpose, format and use of data sheets.

This guide does not cover all possible applications. The specifying engineer must consider the specific installation when filling out the data sheet.

E.2 Scope

The Synchronous Generator Data Sheet covers all synchronous generators rated 500 kW and larger. See the motor data sheet guide, Annex D, for synchronous motors. The Data Sheets are in both metric (m, kg etc.) and US customary (in., lb) units. The line number listed in this guide refer to the US Customary Units version of the data sheet and may vary slightly from the metric units version.

The Synchronous Generator Data Sheet is based on API 546. Paragraph numbers corresponding to API 546 are indicated in (parentheses) on the data sheet where applicable. Features that are called up in the Standard as being the default for that particular item are listed in the Data Sheets as **BOLD**. The default for the item will be assumed by the vendor unless alternate selection is identified. Items for which there are no alternatives (e.g. Stainless steel nameplates) are not shown as options on the Data Sheets. If some other option is desired it should be listed under “Other".

E.3 Symbol Explanatory Page

The initial page of the Data sheet is used to explain how to insert or change the symbols used to mark selections in the digital form Data Sheet proper. The symbols are based on “Wingdings” font and are helpful when filling out the Data Sheets for digital transmission.

E.4 Page 1

Line 2 “Site/Location” Indicates the name of the plant or the equipment train identification.

Line 3 “Supplier” The manufacturer of the machine.

Line 3 “Supplier Project Number” The vendor’s internal identification.

E.4.1 General Information

Line 5 “Applicable to: Proposal, Purchase, or As-Built” Check "proposal" when the data sheet is sent out for quotation, "purchase" when an order is placed, and "as-built" to reflect the completed data sheet after all design details and changes during the manufacture and testing of the generator have been completed.

E.4.2 Basic Data

Line 10 "Applicable Standards" Indicate which standards apply, either North American or International.

Line 11 "Nameplate Power, Synchronous RPM" Power output of the generator, where known. This may be entered by the driver supplier, if the generator and driver are to be purchased as a package. Enter the rated speed of the generator, where known. Available speeds can be calculated by the following equation:

$$\text{Speed(rpm)} = \frac{120 \times f}{p}$$

where

f is the power supply frequency in Hz;

p is the number of magnetic poles in the generator (2, 4, 6, 8, ...).

Line 12 "Volts, Phase, Hertz" For generators, normally specified voltage ratings are the power system bus ratings.

Line 12 "Duty" Almost all petrochemical applications are continuous duty where the machine normally runs continually for long enough to reach thermal equilibrium, which takes some hours. The rare occasions where generators are not expected to reach equilibrium should be described,

Line 13 "Rated Power Factor" Commonly specified power factor ratings are 0.85 and 0.8 (overexcited). The machine power factor should always be specified even when the driver supplier is filling in the nameplate kVA and speed. The power factor is determined by power system requirements.

Line 13 "Insulation Class" Class F insulation is the most common grade used and is rated for 155 C operation. Class H insulation is rated for higher temperatures but is seldom practical for machines of these powers. Class B insulation is rated for lower temperature rise, and is now very uncommon in these ratings. To improve durability, Class B temperature rise (see below) with a Class F system is usually specified so that the cooler running insulation will give long life.

Line 13 "Voltage and Frequency Variations" Enter voltage and frequency variations if beyond standard limits.

Line 14 – 15 "Stator Temperature Rise" and "Rotor Temperature Rise"This is the increase in temperature of the windings permitted over ambient air temperature. There are two methods used to determine the temperature rise: by resistance temperature detector (RTD) and by the measurement of the resistance change (RES), with temperature, of the winding itself. Use the following table to fill in the blank. Temperature rise by "RTD" is recommended when the stator is equipped with RTDs. If not equipped with RTDs, specify by resistance ("RES"). All field winding temperatures are determined by resistance.

Rating or Part	Method	Class B Rise (Above 40 °C Ambient)
Stator Winding		
All ratings	RES	80 °C
1563 kVA and less	RTD	90 °C
Over 1563 kVA 7000 V and less Over 7000 V	 RTD RTD	 85 °C 80 °C
Field Winding		
Salient-pole rotors	RES	80 °C
Cylindrical-rotors	RES	85 °C

The Class B rise given above is specified even though the insulation system is rated for the higher Class F temperature. This is to assure long insulation life. The above values are for a maximum ambient air temperature of 40 °C. If the maximum ambient temperature is above 40 °C up to and including 50 °C, reduce the table values by 10 °C. If the maximum ambient temperature is above 50 °C up to and including 60 °C, reduce the table values by 20 °C. Note that the "Ambient" is taken as the temperature of the cooling air entering the machine. If a heat exchanger is used to cool the air, the ambient will be higher than the outside air or water entering the heat exchanger.

Combustion gas turbines are typically rated based on an air inlet temperature of 15 °C. Non-TEWAC Generators used in conjunction with these turbines are frequently rated to take advantage of the output/ambient curves provided by the turbine makers. As a consequence, the temperature rise of the generator may be higher than the temperatures shown above when operating with cooling air below 40 °C. The total temperature of the insulation system should not exceed 120 °C.

Line 15 "Sealed Exciter Windings Required" Specify sealed exciter windings if there are concerns about excessive humidity, salt or petrochemical contamination.

E.4.3 Site Data

Line 19 – 20—Area Classification "Class__, Division__, Group__, or Zone___, Class___, Group___ or Nonclassified"Use the Class, Division, and Group or Zone, Class, Group as defined in Chapter 5 of the *National Electrical Code* (NEC). Areas are normally defined for existing plants or projects. Refer to API 500 and API 505.

The most commonly specified area classifications are Class I, Division 2, Group D or Class 1, Zone 2, Group D for process areas. "Class I" means a flammable gas or liquid, "Division 2" is where the gas or vapor is present only during abnormal conditions, and "Group D" is a category of materials including gasoline. A "Division 1" area means the gas or vapor is present during normal operation and special enclosures or provisions for ventilation must be used. The IEC Zone system as outlined in NEC Article 505 uses Zone 2 as having the explosive mixture present only during abnormal conditions, similar to Division 2. Zone 1 is when the mixture is present often, and Zone 0 is when the mixture is present constantly. API 505 discusses the Zone system in more detail.

Line 19 "Autoignition Temperature" If nothing is entered, 250 °C is assumed for any ignitable vapors or gases that may exist around the machine while it is in service. Some liquids have ignition temperatures lower than 250 °C, and must be listed here. See the current edition of NFPA 497 for a complete listing of these liquids.

Line 21 "Maximum Sound Pressure Level" 85 dBA at full voltage unloaded is the default. Lower numbers may be desired by OH & S people, but are difficult and expensive to achieve.

Line 22 "Ambient Temperature" Minimum and maximum ambient air temperature. Significant, if below –15 °C (5 °F) or above 40 °C (104 °F). Low temperatures may determine the need for bearing- housing oil heaters or special impact-resistant steel types. High temperatures may determine a derating factor for the generator design or may dictate a special oil cooling system.

Line 23 "Relative Humidity" Indicates the maximum and minimum humidity.

Lines 24-25 "Indoor: Temperature Controlled, Outdoor:, Roof, No Roof" Check as appropriate. Affects the selection of the housing. For example: Requiring a weatherproof housing. If Indoor Temperature Controlled, the operating ambient temperature of the generator may be different than the outdoor temperature.

Line 25 "Site Elevation" Significant if 3300 ft (1000 m) or more above sea level. Machines must be derated or specially designed for higher elevations above this because of the decreased air density.

Line 26 "Nonmassive Foundation Description" The foundation should be designed to meet the massive foundation criteria of 2.4.6.1.2. There may be certain installations where this is not possible, such as on offshore platforms. Detail these structures on the data sheet. A nonmassive foundation may affect the mechanical dynamic performance of the machine. Refer to the description of a massive foundation in API 546.

E.4.4 Unusual Conditions

Line 28 "Dust" If abrasive dust conditions are specified, winding insulation protection is required for drip proof or weather-protected enclosures. This treatment usually reduces the air-cooling effectiveness and raises the winding temperature above that without the treatment resulting in a larger and more costly motor. Specificy any other dust conditions here, such as adhering dust or corrosive dust. See the descriptions of Weather Protected Type I and II enclosures. Totally enclosed machines should be used where possible in these situations.

Line 28 "Chemicals" If the machine is subject to any specific chemicals, vapors, or liquids, specify what those chemicals are.

Line 29 "Seismic Loading" If the machine has significant ducting or unsupported piping (not recommended), indicate the maximum forces to which the frame will be exposed. For example: Uniform Building Code Seismic Zone 2.

Line 29 "Corrosive Agents" Include environmental exposure that could result in stress-corrosion cracking. This may include salt air or trace hydrogen-sulfide.

Line 30 "Other" Indicate any other unusual conditions. For example: Hose down or tropical environment.

E.4.5 Explosion Protected Labeled Generator

Line 32 – 34 For metric data sheets only "Explosion Protection Labeled Generators" There are various standards which may apply to the use of machines in hazardous locations. The selection of applicable standards depends on the geographic location, the local requirements and user preference. Determine the requirements and specify if any of the listed labels are required for the particular application, and whether some form of third party certification is required.

E.4.6 Enclosure

Line 32 "Weather Protected; Type I, Type II" This is a common enclosure. Air from outside the generator is passed through its interior for cooling active parts. Use the Weather Protected Type II (WP II) for outdoor applications. The WP II machine is constructed so that high-velocity air and dirt ingested by the generator can be discharged without entering the internal air passages to the electric parts of the generator. Use the Weather Protected Type I (WP I) for sheltered locations that may be subject to some weather intrusion or water spray. The WP II and WP I enclosures may not be an appropriate choice where adhering dust is present or if the area does not have free air exchange. The hot air discharged from the machine can cause a closed-in area to become excessively hot. WP machines with a rated voltage over 4160 Volts may have a shorter insulation life due to tracking. Note that API recommends utilizing TEAAC or TEWAC enclosures for machines rated 6kV and above.

Line 33 "Air Filters" Filters are recommended for WP machines. The standard recommended filter captures 90 % of 10 micron dust particles. A Differential Pressure Switch or Gauge is recommended to annunciate blocked filters.

Line 37 "Explosion proof" Some manufacturers have machines cetified by a third party National Recognized Testing Laboratory (NRTL) such as Underwriters Laboratories (UL), Canadian Standards Association (CSA), or equivalent international body. Applicable Class 1 Dvision 1 or Zone 1 machines only. Seldom used for this size range and availability may be limited. Only applicable to Class I, Division 1, Groups C and D. For Class II locations (explosive dust), designate "Dust Ignition proof" in "other."

Line 41 "Totally-Enclosed Fan-Cooled (TEFC)" A construction where free exchange of air is prevented between the inside and outside of the machine. It is cooled by a shaft-mounted fan external to the main frame or enclosure that forces air past the outside of the frame. Only available in the smaller ratings covered by this specification, normally less than about 800 kW. This is recommended for severe environments. An alternative for larger sizes is the Totally Enclosed Air-to-Air Cooled (TEAAC) type. See below.

Line 37 “Drip Proof Guarded” This is only suitable for indoor applications and will probably give reduced reliability in all applications.

Line 37 “Totally-Enclosed Pipe-Ventilated (TEPV)” There is no free exchange of air between the inside of the machine and the air immediately outside the enclosure. Used where the machine is located in very dirty locations or if it is installed in a Division 1 or Zone 1 hazardous (classified) location. Requires air inlet and outlet ducts to duct air to and from the enclosure, inlet air filters and usually inlet air blowers.

Line 37 “Other” May include other NEMA or international enclosure designations. It could also designate use of a "Dust-ignition-proof" (DIP) enclosure for Class II (explosive dust) environments. The DIP machine is totally enclosed and is constructed so that dust does not enter the enclosure. It also prevents heat or sparks inside the enclosure from causing ignition outside it.

Line 38 “Totally-Enclosed Air-to-Air Cooled (TEAAC)” Similar in function to the TEFC type. Has an air-to-air heat exchanger, usually mounted on the top of the enclosure, to remove heat from the internal air of the generator by blowing outside air through the exchanger tubes. Use for locations with severe environments not involving adhering dust. Choose the heat exchanger tube material based on what is most compatible with air contaminants. Copper-free aluminum is the default and is less expensive than stainless steel. It is often considered for offshore platforms.

For the use of enclosures in classified areas, see NFPA-70 Section 500 or IEC-60079.

E.5 Page 2

Line 5 “Totally-Enclosed Water-Air-Cooled (TEWAC)” Use in environments with adhering dust or dirt, where it is desired to remove the lost heat from a building, or if the generator is critical and none of the other totally-enclosed constructions are applicable. A source of cooling water is needed, usually about 1 GPM for each kilowatt of loss [(Full Load kW × (1.0 – efficiency %/100)]. The material chosen for the cooler tubes usually is 90/10, copper/nickel.

Line 6 “Redundant Coolers” Redundant coolers are useful if high availability is required.

Line 6 “Exchanger Location” The heat exchanger is most often mounted on the top of the generator. This reduces the floor space requirements but side mounted coolers reduce the risk of water leakage into the machine, and reduce the overall height.

Line 7 “Cooling Water Conditions” The standard cooling water conditions are listed below and in the standard. If they vary from this, changes to the heat exchanger may be required, therefore the water condition should be listed if different to the standard.

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	≥ 100 psig	≥ 7 bar (ga)
Test pressure (minimum of 1.5 times the maximum allowable working pressure)	≥ 150 psig	≥ 10.5 bar (ga)
Maximum pressure drop	15 psig	1 bar
Maximum inlet temperature	90 °F	32 °C
Maximum outlet temperature	120 °F	49 °C
Maximum temperature rise	30 °F	17 K
Minimum temperature rise	20 °F	11 K
Fouling factor on water side	0.002 hr-ft^2 - °F/Btu	0.35 m^2 × K/kW

Line 9 “Tube Construction” Single-tube cooler construction usually is specified with drip trays and leak detectors within the generator. "Single tube" means that the cooling air is in direct contact with the finned tube through which cooling water flows. When a water leak occurs, the generator must be shut down.

Double-tube cooler construction is warranted for nonspared service. "Double tube" means that every tube through which water flows is enclosed within a second tube. The clearance between the tubes is small and empties into a separate header. If a water leak should develop in an inner tube, the leak is enclosed in the second, outer tube and collects in the header. This header usually is equipped with a water detector and will trigger an alarm circuit. Both sets of tubes are rated for the operating water pressure, so no leakage occurs in the air path used for the generator cooling. The generator can continue to operate until a shutdown can be scheduled to repair the cooler.

Line 10 “Flow Sensor” A water flow switch and/or air outlet temperature resistance temperature detector (RTD) is recommended to alarm a loss of cooling water. Normally Open or Normally Closed contacts are dictated by the control scheme. These items are typically supplied by the party supplying the cooling water supply and return pipes.

Line 11 “Air Temperature Sensor” An air temperature sensor is relatively low cost and provides useful data on heat exchanger performance. This should be located in the cold air circuit.

Line 12 “Leak Detection” Leak detection is essential to protect the generator from water leakage. For single tube exchangers the detector is usually in a drip pan above the generator. With double tube exchangers, the detector is in the outer tube header.

Line 14 “Provision for Pre-Start Purging” Specify this for hazardous locations if it is desired to replace all the possibly explosive atmosphere with air from a non hazardous location before starting up. Seldom required for generators and only applicable to totally enclosed machines.

Line 14 “Marine Grade Stainless Steel Fasteners” Recommended for corrosive environments. Common zinc-plated steel fasteners will corrode and make machine disassembly and maintenance difficult. Stainless steel fasteners may cost more, depending on the machine size and the manufacturer's pricing policy. There is a risk of stainless fasteners galling and being difficult to remove unless anti seize compound is used.

Line 15 “Degree of Protection IP” “Method of Cooling IC” These two items define the type of cooling required and how well it should protect the generator. Definitions are provided in NEMA MG-1 and IEC.

E.5.1 Mounting

Line 18 “Horizontal, Foot Mounted; Flange Mounted” Almost all generators in this category are horizontal type. Specify "foot mounted" for most applications. Flange mounted generators are rare in these ratings.

Line 19 “Vertical, Shaft up, Shaft down” List the few situations where vertical configuration is used.

Line 20 “Pedestal” Check if a pedestal style generator is required.

Line 20 “Axial Stator Shift Required” Many synchronous machines have their bearings mounted onto "bearing brackets" attached to the frame, so axial stator shift is not required. Stator Shift is where the stator assembly is axially re-located on the soleplate or base without removing the outboard bearing to expose the rotor poles to facilitate maintenance or removal. It usually applies to engine type generators with only a non-drive-end bearing where the drive-end bearing is integral with the driver. If the generator is to be supplied through a driver vendor, and you are unsure of a response, indicate a "Note" on the data sheet for the driver vendor to complete this.

Line 21 “Engine Type, Bearings Furnished By ___; Shaft Furnished By ___” An engine type generator is typically slow speed and shares at least one of its bearings with the driver. Typically indicate that the generator supplier is to supply the bearings and the shaft.

Line 22 "Baseplate Furnished By" If a baseplate is furnished, it usually is by the driver supplier as part of a package. Most such generators have soleplates. See below.

Line 22 "Soleplate Furnished By" Soleplates are steel plates embedded into a concrete foundation onto which the machine is mounted. They are normally furnished by the generator supplier for installation by the purchaser.

Line 23 "Special Connections for Field Piping" Where non-standard piping connections will be used for any water or lube-oil connections, indicate here.

Line 24 "When Rotor Dynamic Analysis is Specified, List of Foundation Data Required from Purchaser" The generator supplier must specifically request the data required so they can perform the analysis. In order for the generator supplier to perform this analysis, dynamic "stiffness" values, or other information may be required. This usually is expressed in millions of kilograms per centimeter (pounds per inch) for both the horizontal and vertical directions. The foundation designer should be consulted in order to provide this data.

E.5.2 Electrical System

Line 28 "Primary Power Source: Volts, Phase, Hertz" Indicate the nominal voltage, the number of phases, and the frequency of the electrical system to which the generator will be connected.

Line 29 "Method of System Grounding, Maximum Ground Fault Amperes" Specify how the power system source to the generator is to be grounded. Most applications are either low-resistance grounded (50 to 400 amperes) or high-resistance grounded (10 amperes maximum). Some systems have "delta" connected transformers at their source with no intentional connection to ground and are "ungrounded." The method of grounding affects the voltage rating of surge arresters applied to the generator. The generator neutral is also often grounded either directly, through a resistor, or through a transformer/resistor configuration. This should be specified.

Line 30 "Fault Current at Machine Terminals____MVA" Enter the maximum momentary or $^1/_2$ cycle short circuit level (MVA) that can be delivered by the power system. Typically use the maximum expected supply switchgear or circuit breaker duty. This is for determining terminal box pressure release or withstand and coil bracing requirements.

Line 30 "Let-Through Energy____I^2L" If the generator feeds the system through a fused contactor (less likely with a synchronous generator) enter the maximum let-through energy in ampere squared seconds for the selected fuse that results from the maximum system short circuit capacity.

Line 31 "Parallel Operation Requirements with Existing Equipment" Real and reactive load sharing between generators requires the vendor to know power system and machine details. Provide vendors with requirements plus power system and machine data.

Line 33 "Other" This may include details on the electric power system such as "fast-bus transfer" of the supply during power failure or line reclosure during system short circuits which could affect winding mechanical bracing and the shaft design.

E.5.3 Bearings

Line 35 "Bearing Type" "Normally check "hydrodynamic" For this size and type of machine, the hydrodynamic ("oil-film") type bearing is most suitable and is the default selection. This contrasts with the antifriction ("ball/roller") type bearing. The machine vendor typically selects the bearing type (Cylindrical, Elliptical Tilt Pad, etc.) to meet the stiffness and damping requirements of the lateral critical speed study.

Line 35 "Oil Ring Required" Most machines of this size rely on a lubrication system (see below) to move lubricating oil through the bearings. If the power supply to the lubrication skid fails, it is essential to keep oil in the bearings during coastdown. One way to achieve this is with oil rings which take oil from the bearing sump to the bearing itself. Other methods include a "run down tank" or a DC motor driven pump. Most cylindrical sleeve bearing designs permit oil rings, but some others do not. If they can be fitted and if they provide enough oil to prevent high temperatures during coastdown, rings are desirable.

Line 37, 38 “Thrust Bearings, Maximum Connected-Equipment Thrust” Usually leave blank. Applicable only to a machine with a vertically oriented shaft. The prime mover supplier would normally enter this data for vertical machines. Both momentary and continuous figures are required for up and down thrust

Line 39 “Bearing Constant-level Sight Feed Oilers Required” Specify where the generator has self-lubricated bearings. Constant level oilers are not recommended on larger machines where the volume of the bearing housing far exceeds the volume of the oiler.

Line 40 “Special Seals for Gas Purge” Specify for totally enclosed machines that will operate in severe dust or dirt environments. A clean, dry air (or other gas source) must be available. Full details on the system requirements shall be provided by the specifier.

Line 40 “Non-conducting Seals” Some bearings may require non-conducting seals for electrical isolation reasons.

E.6 Page 3

E.6.1 Lubrication System

Many points in this section are determined by the generator vendor, package vendor and purchaser working together.

Line 4 “Self Lube” This is practical for smaller machines where the bearing losses can be dissipated without external heat exchangers.

Line 4 “Pressurized Lube Required” Indicate if a pressurized lube or flood lube system is required. This is recommended for all machines rated above approximately 1500 kVA.

Line 4 “System Supplied By, Common with Driver” When the prime mover has a pressurized lubrication system, the generator typically is fed from the same system, although shared systems pose a risk of gasses entering the generator through the lube system. This space is for selecting such a system, designating its supplier, the lubricating oil type, quantity of oil, and the supply pressure. An oil system is typically supplied by the prime mover supplier.

Line 5 “Per API 614,” API 614 is a comprehensive, lubrication system specification necessary for applications those type of bearings that cannot be supplied with backup oil rings. This type of system would accompany a compressor and may be common for both the motor and driven-equipment; however, some users prefer to have seperate systems. If an API 614 lubrication system is needed, select either General Purpose or Special Purpose. Slow Speed or non-critical applications may be suitable for General Purposed and high speed or critical applications will normally require Special Purpose.

Line 5 “Main Oil Pump Required, Integral Shaft Driven, Separate” If an API 614 system is supplied, or if backup oil rings are supplied, a main oil pump driven by the shaft is not required. API 614 usually recommends a primary standby pump which must be designated on the data sheet.

Line 6 “Oil Rings Not Provided” Selected only where oil rings cannot be applied (i.e. tilt-pad bearings) or are not otherwise required. See page 2, Line 35 for further oil ring information.

Line 7 “Type/Viscosity of Oil” Usually specified by the manufacturer, a typical oil for a common system is ISO Grade 32. The oil system pressure is typically 100 kPa to 180 kPa (15 psig to 25 psig).

Line 9 “Oil Mist for Antifriction Bearings” In the rare cases where antifriction (ball or roller) bearings are utilized, this alternate method of lubrication is not often used, and is user/application specific.

E.6.2 Special Conditions

Line 12 “Shaft and Spider one piece forging for 4 or more poles” A one piece forging is required for 2 pole machines. An integral shaft/spider is recommended for 4 and 6 pole machines.

Line 13 “Special Vibration Requirements” For critical equipment (e.g. unspared, high speed, or other sensitive applications) lower vibration limits may be specified.

Line 14 “Efficiency Evaluation Factor” See below to determine the "$/kilowatt" to be used for the evaluation of bids based on quoted efficiency. Should be completed for all machines. See also API 540 for further information.

Generators should be purchased on the basis of LCC. LCC is the purchase price of the machine plus the value of losses over the its life using the EF and KWe shown.

$$LCC = P + EF \times KWe$$

where

- P is the purchase price of the generator in dollars;
- EF is the EF ($/kW) = $C \times N \times PWF$;
- C is the energy cost in $/KWH (Dollars per Kilowatt-Hour);
- N is the operating time in hours per year;
- PWF is the cumulative present worth factor (this factor typically ranges from 2 to 4 It is dependent on interest rates and expected life cycle for the purpose of bid valuations);
- KWe is the KWe in (kW);
- KWe is equal to $L \times$ kW $\times$ [(100/Eop) - 1];
- L is the load factor = (output kW)/(Nameplate kW); and
- Eop is the generator efficiency (in %) at the specified kVA and power factor load.

Line 15 “National, State/Provincial, Local Codes"—List and supply copies of any local, special codes. The copies are required by the API 546 paragraph. For example, southern California installations frequently call for special electrical codes.

Line 16 “External Forces on Generator Housing That May Affect Site Performance” Indicate any forces from piping, ducting, or any auxiliary equipment not provided by the generator supplier. Typically, these loads can be minimized when these items are properly supported.

Line 17 “Special Overspeed Requirements” Machines are normally purchased with the ability to withstand an overspeed specified by NEMA MG-1 (2 min at 20 % overspeed for 1500 rpm and over, 25 % for 1499 rpm and lower) or IEC 60034 (20 % overspeed). These limits are generally satisfactory but for unusual power system or governor cases, capabilities beyond the regular limits may be required and should be listed here.

E.6.3 Main Conduit Box

Line 21 “Box Location”Enter which side of the generator the main terminal box is to be mounted with reference to the non-drive end (exciter end). For example: right side from NDE.

Line 21 "Conductor size, type, insulation and quantity per phase" For the main power cables to the machine, enter the conductor size, type, insulation as well as the number of cables per phase. A specific catalogue reference for the size and type of cable often eliminates any doubt.

Line 22 "Quick Disconnect Type Bushing Studs or Receptacles" These are infrequently specified. Used where a fast change of generators is required in the event of a failure. Specify the type of stud or receptacle.

Line 23 "Space for Termination of Shielded Cables" Terminating shielded cables requires additional space that may require a modification to main terminal box. If shielded cables are utilized select this option and provide specific details to the manufacturer.

Line 23 "Cable entering from" Indicate the position of the main supply cable entry to the main terminal box. (Special consideration should be given to generators specified with stator shift—see 1.5.17 and 2.4.2.15)

Line 24 "Both Ends of Stator Winding Brought out to Terminal Box" This is common on these machines and is required if differential relaying current transformers are used. It also facilitates insulation testing on individual phases and should usually be specified. Some machines have the line and neutral ends bought out to different boxes, and this should be noted if required.

Line 24 "Thermal insulation" This should be considered in locations where moisture condensation on cool metal surfaces is common, or where personal protection is required from elevated surface temperatures. It should be specified where terminal box space heaters are provided. See line 26.

Line 25 "Cable between Stator Windings and Main Terminals" Some users have had problems with the stator winding to terminal box cables failing for various reasons. One remedy to this situation is to use bus and/or extended winding sections for the leads. Each manufacturer has slightly different methods, each with positive and negative features. This point should be discussed if the purchaser has concerns in this area.

Line 26 "Space Heaters" Specify heaters in the main terminal box if the unit is to operate in an outdoor or humid environment or when the generator is expected to be unenergized for long periods of time.

Line 27 "Differential protection current transformers" Recommended for all unspared applications and all generators rated 2,500 kVA and larger. There are two current differential protection schemes for generators: phase differential and self-balancing differential protection. Phase differential protection uses six identical current transformers, one pair for each phase. Three of the current transformers are located at the generator switchgear and the other three in the three phases at the generator winding neutral. Self-balancing differential protection uses three zero-sequence, window-type, current transformers installed at the generator terminal box. One current transformer per phase is used with the generator line and neutral leads of one phase passed through it such that the two currents normally cancel each other. The self-balancing scheme is commonly applied. It usually has a lower primary pickup in amperes and provides stator winding phase and ground protection. This scheme does not detect cable faults. The phase differential scheme has the advantage of protecting both the generator stator winding and the generator feeder cables in the differential protection zone. However, this arrangement can be prone to unbalancing of signals and nuisance tripping due to instrument wire failure. Appropriate protective relays must be provided in the generator switchgear. Core-balance, or window type, current transformers are the most common. Either specify the specific type (e.g. type BYZ) or the current transformer accuracy class. A "C 10" accuracy class is usually adequate, but "C 20" may be required depending on the protective relay type. Recommend a "C 10 accuracy class" for "type" and a ratio of 50 to 5 (50:5) for self-balancing. Since phase differential current transformers carry load current, they must have primary current ratings chosen accordingly. Bar-type current transformers are only applied for very high continuous current ratings, and are specified with appropriately high ratios and accuracy classes to match a set of three current transformers in the supply switchgear. Specify who will supply and who will mount the current transformers. (For phase differential systems it may be advisable to have all six current transformers purchased with the switchgear and three supplied to the generator manufacturer to ensure all six are matched correctly.)

Line 29 "Surge capacitors" Are connected between each phase and ground to decrease the slope of the wavefront of lightning surge voltages and switching surge voltages. Recommended for unspared machines, those connected through one transformer or directly to a bare overhead line, or those which have switched capacitors on the same voltage level. Specify 0.5 microfarad for voltage ratings through 4160 volts and 0.25 microfarad for ratings 6600 volts and above. Surge capacitors may or may not be used in conjunction with surge (lightning) arresters. Specify who will supply and who will mount the surge capacitors.

Line 30 "Surge arresters" Are installed one per phase connected between the phase and ground, to limit the voltage to ground impressed upon the stator winding due to lightning surges. Recommended for the same conditions given for surge capacitors. For those machines connected to a bare overhead line through at least one transformer (protected on its primary with arresters), one set of surge arresters applied on the main switchgear to protect a group of machines is usually adequate. Specify 2.7kV rated arresters for 2.4kV rated generators, 4.5kV for 4.16kV, 7.5kV for 6.6kV, and 15.0kV for 13.8kV machines. The arrester voltage ratings are usually adequate if a ground fault will be cleared in one second, that is, low resistance grounded systems. However for high resistance grounded systems where fault clearing is not immediate, the arrester MCOV rating must be greater than the system line to line voltage. This would mean 3kV arresters for 2.4kV generators and 5.1kV or 6kV arresters for 4.16kV generators. Specify who will supply and who will mount the surge arresters.

Line 31 "Current Transformers for Ammeter" If a single current transformer is needed for load-current indication local to the generator, or other purposes, specify the type (usually a window type) and ratio with a maximum current rating of 150 % of the rated-load current of the generator. An alternative is to use a current transducer mounted in the switchgear wired to an ammeter mounted at the generator.

Line 33 "Potential Transformers for Voltmeter" Rarely specified, except on some captive transformer applications where there may be no switchgear available at the generator voltage to extract a voltage. (Adds complication, space requirements, and a potential failure point within the terminal box.) If required, include details on who is to mount them, the quantity, the ratio and the accuracy class. Also specify if fuses are required. If the area is classified, most applications of fuses within the terminal box necessitate purging the terminal box.

Line 35 "Provisions for Purging" Purging is required by the *National Electrical Code* for terminal boxes having surge arresters mounted within the terminal box when the generator is installed in a Class I, Division 1 or Zone 1 area. Specify for this condition.

Line 36 "Removable links" Recommended for machines with larger terminal boxes to permit isolation of each phase from the incoming cable and surge protection. This permits maintenance high-potential or insulation tests to be done without needing to remove stress cones and disconnection of devices in order to isolate the windings.

E.6.3.1 Line 36 "Silver- or Tin- Plated Bus Joints" Recommended for bus links and cable terminations to reduce contact resistance from corrosion. Tin is recommended for locations where sulfur is present

E.6.3.2 Line 36 "Ground bus" Should be specified for all generators.

E.6.3.3 Line 37 "Insulated Terminations and Interior Jumpers" The risk of a phase to phase or a phase to ground fault is reduced if the internal conductors are insulated. This should be specified in most cases.

E.7 Page 4

Line 4 "Frame space heaters" All generators should include space heaters. Normally, the "manufacturer's standard" bar type heater sheath material is acceptable, but stainless steel or other material could be specified. Flexible belt type space heaters should be avoided, and any type of heater that contacts the surface of the generator winding is not acceptable. Specify 120- or 240-volt, single-phase or 208- or 480-volt, three-phase power, depending on what power source would be available with the generator shut down. Temperature Code is defined by the maximum temperature permitted at the surface of the heater element, which could be a source of ignition in an explosive atmosphere if the element is too hot. For Class I (gas or vapor) Group A, B, C or D locations, specify the Code for the lesser of 200 °C or 80 % of the autoignition temperature from NFPA 497 for the specified gas or vapor involved.

Line 5 "Bearing heaters" Not specified very often, because most generators in extremely cold climates are installed in heated shelters. Where needed to bring lube-oil in the bearing housing sump up to the minimum temperature recommended by the manufacturer, specify a type that can conform with API 546 specifications. If an electric immersion heater is used, it shall have a maximum watt density of 2.3 watts per cm^2 (15 watts per $in.^2$) to avoid carbonizing the oil.

Line 6 "Exciter Space Heaters" Normally specify as for frame space heaters.

Lines 4, 5, 6 "Temperature Code" This is defined as the maximum temperature permitted at the surface of the heater element, which could be a source of ignition in an explosive atmosphere. For Class I (gas or vapor) Group A, B, C or D locations, specify the Code for the lesser of 200 °C or 80 % of the autoignition temperature from NFPA 497 for the specified gas or vapor involved. The chart below is taken from NFPA 497 and lists liquids with an AIT less than 200 °C.

Table E.1—List of Liquids with an Autoignition Temperature (AIT) of Less than 250 °C, Requiring Space Heaters with Heater Element Surface Temperature Less Than 200 °C (Extracted From NFPA 497-2008)

Material	Group	AIT °C	80 % AIT °C
Acetaldehyde	C	175	140
Acrolein (inhibited)	B(C)	235	188
Allyl Glycidyl Ether	C	57	46
n-Butyraldehyde	C	218	174
Carbon Disulfide	—	90	72
Crotonaldehyde	C	232	186
Cyclohexane	D	245	196
Cyclohexene	D	244	195
Cyclohexanone [a]	D	245	196
Decene [a]	D	235	188
Diethyl Ether	C	160	128
Diethylene Glycol Monobutyl Ether [b]	C	228	182
Diethyl Glycol Monomethyl Ether [b]	C	241	192
Dimethyl Sulfate [b]	D	188	150
1,4-Dioxane	C	180	144
Dipentene [a]	D	237	189
Ethylene Glycol Monobutyl Ether [b]	C	238	190
Ethylene Glycol Monoethyl Ether [a]	C	235	188
2-Ethyl Hexanol [b]	D	231	184
2-Ethylhexaldehyde [a]	C	191	152
Fuel Oils [a]	D	210 to 407	168
n-Heptane, n-Heptene	D	204	163
n-Hexane	D	225	180
Hexenes	D	245	196

Table E.1—List of Liquids with an Autoignition Temperature (AIT) of Less than 250 °C, Requiring Space Heaters with Heater Element Surface Temperature Less Than 200 °C (Extracted From NFPA 497-2008) (Continued)

Material	Group	AIT °C	80 % AIT °C
Hydrazine [a]	C	230 to 270	—
Isoprene	D	220	176
Iso-octyl Aldehyde [a]	C	197	157
Kerosene [a]	D	210	168
Methyl Formal	C	238	190
2-Methyloctane	D	220	176
3-Methyloctane	D	220	176
4-Methyloctane	D	225	180
Methylal	C	237	190
2-Methyl-1-Propanol	D	223	178
Monomethyl Hydrazine	C	194	155
n-Nonane	D	205	164
n-Octane	D	206	165
Octene	D	230	184
n-Pentane	D	243	194
Propionaldehyde	C	207	165
n-Propyl Ether	C	215	172
Propyl Nitrate	B	175	140
Triethylamine	C	249	200
Unsymmetrical Dimethyl Hydrazine	C	249	200
Valeraldehyde	C	222	177

[a] Flash point of these materials is between 100 °F (37.8 °C) and 140 °F (60 °C). Special electrical equipment is required only if these materials are stored or handled above their flash points.
[b] Flash point of these materials is between 140 °F (60 °C) and 200 °F (93.3 °C). Special electrical equipment is required only if these materials are stored or handled above their flash points.

Lines 4, 5, 6 "Volts, phase and kW" Due to typical low power requirements (100 to 150 watts) a single phase 120 or 240 volt power supply is selected.

Line 7 "Winding Temperature Detectors" These detectors are installed in intimate contact with the winding insulation and give an accurate measurement of the operating temperature of the winding. They provide better protection for the generator than current-sensitive overload relays. They also improve protection against clogged air filters which can cause high winding temperatures in weather protected (WPI and WPII) enclosures. This specification requires three 1000 hm platinum at 0°C RTDs per phase, equally distributed around the stator winding (3.2.1.2). Other types may be used where required to interface with existing monitoring systems. Typical resistance temperature detectors (RTDs) are 100 Ω at 0 °C, platinum, 3 wire, with a temperature coefficient of resistance (TCR, Ω/Ω °C) of 0.00385 per EN 60751, Class B. Other types are 120 Ω at 0 °C Nickel 2 wire and 10 Ω at 25 °C Copper 3 wire. The need to ground one lead is dependant upon the instrumentation requirements. Typically one lead is grounded at the generator.

Line 8,9 "Other Detector, Thermocouples" Other means of detecting overtemperature or measuring winding temperature such as non linear resistors or thermocouples are available but are more often used in smaller machines.

Line 11 “Monitor for Shaft Grounding Brush Replacement” Some machines are supplied with a shaft grounding brush to keep shaft voltage down. If the brush wears out the shaft may build up voltage, causing a hazard. Monitoring systems are available to annunciate the need for brush replacement and should be specified if shaft voltage buildup is a concern. Operation in a hazardous (classified) location may preclude the use of shaft grounding brushes due to arcing/sparking considerations, or the implementation of special means to allow their use. A monitor cannot alter the acring/sparking nature of shaft grounding brushes.

Line 12 “Test Device for Rotating Electronic Components” Systems are available which can be easily connected to the machine and are able to assist with troubleshooting the rotating electronic components. The availability and features should be discussed with vendors.

Line 12 “Rotating Diode Failure Detection” Exciter rotating diode failure can be detected by stationary devices which monitor the waveform of the exciter current. This feature can be useful in analyzing failures and annunciating problems.

Line 13 “Online Rotor Monitoring System” Systems are available which can give data on machine rotor winding resistances, temperatures etc. as well as detect ground faults. The availability and features should be discussed with vendors.

Line 14 “Exciter Power Supply” A reliable power supply for the exciter is essential for operation through brief dips in power system voltage. Possible sources are a permanent magnet generator (PMG) which is most common with alternator excitation, a CVT which gives a constant output for a range of input volts, a phase controlled rectifier which is essentially oversized for the application, or feeding the exciter power from an UPS. Choose the most practical for the application.

Line 16 “Auxiliary Equipment Enclosures” List the auxiliary equipment location as determined by the equipment layout.

Line 18 “Hydrodynamic or Thrust Bearing Temperature Devices” These detectors should be applied consistent with the entire equipment train. They usually are applicable to large (1000 kVA and greater) and special-purpose equipment trains. They can provide early warning of lube-oil loss or impending bearing failure. API 670 outlines requirements that assure accurate bearing-metal temperature measurement. When temperature detectors are installed, they shall be 100 ohm at 0°C platinum 3 wire per EN 60751, Class B (3.3). Other types may be used where reacquired to interface with the existing monitoring systems.

Line 19 “Provision Only, Install per API 670, Other” Where future capability for installation of sensors or use of sensors during factory tests is desired, specify “provisions only.” A “manufacturer's standard” installation may not represent the true bearing metal temperature since generator manufacturers often monitor the bearing shell temperature, an inch or more from the shaft-bearing interface. If bearing temperature monitoring is specified, “API 670” requirements are recommended since the temperature-sensing tip location is defined at the most representative place on the bearing.

Line 20 “RTD: Type” RTDs shall be 100 ohm at 0°C platinum 3 wire type per EN 60751 Class B (3.3). Other types may be used where reacquired to interface with existing monitoring systems.

Line 21 “Thermocouple: Type” Iron constantin (Type J) can be specified, for example, where a thermocouple is desired.

Line 22 “Dial-Type Thermometer, Alarm Contacts” Only applied to nonpressure-fed bearings. Specify where an indication of the oil temperature is desired. If alarm contacts are required for annunciation, indicate "yes" and the type and number of contacts under "alarm contacts."

Line 23 "Location of Bearing Temperature Sensor Wire Terminations" Indicate the location of the detector terminations. Often, separate terminal heads are supplied and the external conduit is run to each head. The detector terminations could also be enclosed in the same terminal box as the winding RTDs.

Line 24, 25 "Recommended Settings" Normal alarm temperature is 80 °C. If applicable, normal shutdown temperature is approximately 100 °C. Machine vendor will supply recommendations.

Line 26 to 31 "Vibration Detectors" Specify devices consistent with the equipment train. For generators operating at 1200 rpm and higher, two probes per bearing and a phase reference probe should be installed (3.8.1). (For slower speed machines, consideration should be given to bearing housing seismic sensors—see line 34.) Two externally adjustable probes per bearing are normal (90 degrees apart), but four probes per bearing may be desired if the probes are not accessible during operation and vibration monitoring is considered important (usually only two oscillator/demodulators are supplied for each bearing, since the probe wires can be exchanged during operation).

Certain slow speed applications often make use of a phase reference probe without the need for any proximity-type vibration probes.

Line 34 – 35 "Bearing housing seismic sensors" Specify consistent with the equipment train. Often applied on generators with eight or more poles. Accelerometers should be specified using API 678, or velocity pickups may be specified. Specify acceleration, velocity, or displacement transducer output for accelerometers (velocity output is recommended); velocity or displacement transducer output for velocity pickups. Spot-faced surfaces can be specified for future mounting of transducers. Specify the location of the sensors—"H" horizontal, "V" vertical and/or "A" axial.

Line 38 "Vibration Switch" These devices are not normally recommended for generators of the size range covered by this specification, since they offer less protection than API 670 or API 678 systems.

Line 40 "Alarm and control switches"—Where auxillary devices or sensors use switch type contacts, they shall be a minimum of Single Pole Double Throw (SPDT) and rated for a minimum of 10 amps at 115 VAC. Special notation is required for DC rated switches.

Line 41 "Partial discharge detectors" Partial discharge levels and phase relationships can be used to assist in the predicting of insulation failure. This has proven to be quite effective for systems above 4160 volts. With systems rated 4160 volts and lower, partial discharge monitoring and analysis gives a shorter warning time than when used for higher voltage systems. Various sensor types are used, and the desired type should be specified.

Line 43 "Separately Powered Auxiliary Fan(s): Driver Information" Some types of enclosure use separately powered fans to move air through the generator. The motors and fans, as well as their power sources, should be reliable. Auxillary powered device motors shall be per IEEE 841 (2.4.10.6.3).

E.8 Page 5

E.8.1 Controls

This section lists the control and excitation requirements. Many of the requirements are derived from power system analysis, possibly with utility input.

Lines 4 to 8 These lines describe parts of the excitation system. The types of excitation systems are defined by IEEE for ease of including in a power system analysis program. The gains and time constants are to be presented by the vendor in the IEEE format for use in the stability simulations. Most brushless excitation systems are Type 2 rotating rectifier system.

Line 10 "Voltage Regulator" This is usually supplied by the generator vendor, but if the purchaser has any preference, based on power system questions or established practice, this should be listed.

Line 12 "Permanent Magnet Generator Excitation Source" This is one way of providing a stable source of power for the exciter, so that full excitation can still be supplied when the bus voltage drops for some reason, such as a short circuit or motor start. It is recommended for most applications.

Line 13 "High Initial Response Excitation System Required" This is recommended for generators in critical service or those that are called upon to start motors with horsepower rating greater than 15 % of the generator kVA rating. It generally improves the dynamic stability of a generator.

Line 20 "Power System Stabilizer Required" This is generally used for machines over about 10000 kVA operating synchronized to the utility. It adjusts the generator excitation to reduce generator power swings. Check with the utility for generation interconnection requirements, which may include stabilizer specifications. If a power system stabilizer is specified, the vendor's proposal should include enough data on transfer functions, filter parameters, gains and time constants to confirm its adequacy with the utility.

Lines 22 to 24 "Manufacturer's Standard Excitation Control" If the vendor's standard excitation package is satisfactory, list it here. It may be shipped to the switchgear vendor for installation there, or be part of a separate control panel, as required by the project. A seperate, free-standing control cubicle may also be available.

Line 25 to Page 6 Line 19 "Completely Assembled Control Panel with Devices as Checked, Separate Devices as Indicated" Where particular requirements exist, specify these. These devices are then usually mounted in space provided in separately purchased switchgear or sometimes in a separate, free-standing control cubicle provided by the generator vendor, as specified. The trend is to include as much metering as possible, due to the relatively low cost of metering.

Vibration probe monitors are usually combined with the driver monitors, not in the generator panel.

Synchroscopes are used for manual synchronizing. A synch check relay is usually desirable to prevent out of phase synchronizing. Most modern installations use an auto synchronizer which adjusts the speed, voltage and phase difference to achieve a breaker closing with minimum transients.

Dual voltage regulators are desirable for critical applications. They can be configured so that if one fails, the backup unit can take over with minimum transients.

Volts/Hertz limiters are commonly used to avoid excessive flux density and core heating at low speeds. This feature is often included in most regulators.

A constant voltage control power transformer is needed only if a permanent magnet generator is not used to supply power.

Other items as listed may be ordered when necessary.

AC or DC control contacts should be specified as required for the particular situation.

Top, bottom or side wiring entrance is usually site specific.

E.9 Page 6

E.9.1 Driver Equipment Information

Line 21 "Prime Mover Equipment Tag No" Enter identification number description and location of the prime mover.

Line 23 "Driver Equipment Mfr." Enter the name of the driver equipment manufacturer. **"Type/Model"**— Enter the specific type or model number of driver. "RPM" Enter the rated speed of the driver equipment. This will be different from the generator speed if a gearbox is being used.

Line 24 "Driver Connection to Load" Check one of the following:

"Direct Connected" Check, if the generator is directly coupled (at the same speed) to the prime mover (i.e. not coupled through gears.).

"Gearbox" Check, if applicable.

Line 25—Speed Increasing-Reducing Gear"—List the ratio of speed-increasing or speed-decreasing gearboxes.

Line 25 "Speed Increasing-Reducing Gear GD^2/WK^2" If known, enter the rotational inertia of the gear at a specified RPM, usually the generator speed.

Line 27 "Generator Shaft Extension" The generator shaft extension may be cylindrical, tapered or flanged. The type is determined by the coupling that is specified.

Line 28 "Rotation Viewed From Opposite Drive End of Generator" Indicate the direction of rotation as viewed from the exciter end (the non-drive end) of the generator. Indicate clockwise, counterclockwise, or bi-directional

NOTE The direction of rotation of some units must be designed and manufactured accordingly, and cannot be changed in the field without major consequences.

Line 29 "Coupling" Enter "gear," "diaphragm," "resilient," etc., as appropriate. Include the coupling manufacturer and model number.

Line 31 "Coupling GD^2/WK^2" Enter the rotational inertia of the coupling at a specified RPM, usually the generator speed.

Line 32 "Mass Moment of Coupling Half" This data is required for the mechanical dynamic analysis.

Line 32 "Supplied By" Most often, the prime mover supplier provides the coupling, unless the purchaser is coordinating the interfaces between equipment.

Line 33 "Mounted By" Most generators ordered through a prime mover manufacturer have their coupling-mounted by the manufacturer. Generators rated 1500 rpm and greater usually undergo a rotor dynamics test and requires that the coupling be mounted by the generator manufacturer. Coordination is required at the time of order entry to assure the coupling half, with its idling adapter which allows the generator to be run uncoupled, is properly coordinated. For example: The coordination may involve special tapped-hole patterns on the idler plate for adaptation to a balancing machine drive.

E.9.2 Miscellaneous

Line 36 "Painting" The standard painting is normally accepted unless the machine is to be installed in a severe environment, such as offshore. If special paint is specified, include the surface preparation and paint specifications with the quotation request to the manufacturer. Consideration should be given to the painting system used on the inside surfaces of a WP enclosure.

Line 36 "Special Weather Protection" List any special needs here.

Line 37 "Proof of Nonsparking, Corrosion-Resistant Fan" This is usually only specified for generators rated for speeds of 1800 rpm and higher.

Line 37 "Quantity of Special Tools and Lifting Required" The manufacturer should indicate here that non-commercially available tools are required for the assembly or maintenance of the machine. Normally, one set is adequate.

Line 38 “Special Low-Temperature Materials Requirements” This section applies to operating temperatures less than –29 °C (–20 °F). At low temperatures many steels become brittle. Alloys that remain ductile at the minimum operating temperature shall be used.

Where machines are operating in temperatures of –20 °C (–40°F) r lower, it is necessary to ensure that steel components operating under stress are made of an alloy that is capable of maintaining its mechanical properties at reduced temperature.

Line 39 “Special Winterizing Requirements” Specified where winter conditions exist prior to start-up. This is specified so the machine supplier can identify protective items and identify the items that they will furnish.

Line 40 “Materials to be Identified With Applicable ANSI, ASTM, or ASME Numbers” If certain parts identified by standard designations are required, list them here. This may include flanges, minor hardware, shaft material, bearing babbitt alloy, etc.

Line 41 “Typical Drawings and Literature with Proposal” Indicate when the purchaser requires typical drawings and assembly instructions included with the proposal.

“Electronic Instruction Manuals” Indicate here if the purchaser requires instruction manuals to be provided in electronic format.

“Photos Showing Assembly Steps Required” Indicate here if the purchaser requires photos showing the step by step assembly of the machine or components such as bearings.

Line 42 “Performance Curves Supplied in Digital Format” Some power system analysis software can accept generator data directly, without having to key in the data. Specify the required format here.

Line 43 “Manufacturer to Supply Curve Data in Tabular Format” If keying in the generator data is desired, check this box.

Line 43 “NRTL Certification, PMI Certification” If documentation is required to have certification from a NRTL or to have positive material identification, list here.

Line 44 “Detailed Instructions and photographs for disassembly and inspection” For machines that have unusual features, or if the maintenance people are not familiar with large machines, it may be helpful in the future to have photographs detailing its arrangements.

Line 44 “Certified Drawings Qty” Inform the vendor how many copies of the certified drawings are required.

E.10 Page 7

Line 4 “Type Tests and Design Information Verifying all Gasket Materials are Impervious to Lube Oil and Chemicals” If there are concerns about lube oil or chemical attack on gasket material, specify this information be supplied.

Lines 5 “Special Identification for Transmittals” Any special identification for drawings, correspondence, etc. should be entered here.

“Separate Nameplate with Purchaser’s Information” If a special nameplate is needed for identifying the equipment number or other information, detail the requirements here.

Lines 8 to 11—“Shipment”

Line 8 “Domestic” Depending on the protection inherently offered by the enclosure, specifying this would include the protection described in API 546 and coverage of the generator by a tarpaulin or plastic sheeting. Specifying export gives heavier packaging.

Line 8 “Export Boxing Required” Would normally include complete, sealed coverage with desiccant and a substantial box is built around the machine. The manufacturer should describe the preparation included when the proposal is presented.

Line 8 “Commissioning Assistance Required” Indicate here if the purchaser wants the manufacturer to provide assistance during field assembly or commissioning. There is an additional fee charged for this type of service typically quoted on a daily rate.

Line 8 “Mounted on Skid” The generator is normally mounted on a rigid skid as a base for shipping.

Line 9 “Special Shipping Bearings” These are specified to prevent damage to the normal running bearings due to abnormal handling during shipment, such as impact, dropping and railyard humping. Normal handling during shipment does not usually affect the bearings, so it can be considered an "insurance policy" for machines in which timely start-up is necessary. The use of shipping bearings alone, however, does not prevent damage to other parts from this type of abuse. Critical shipment should include "g" (acceleration) recorders to monitor handling.

Line 9 “Outdoor Storage for More Than Six Months” Indicate if this is to be the case. Special storage provisions may be recommended by the machine supplier.

Line 9 “Piping Assembled” Can be considered where coolers or lube oil piping are to be supplied by the generator supplier. Checking this bullet requires the manufacturer to ship all piping assembled on the unit, rather than in seperate pieces or sub-assemblies. While this may facilitate installation at the site, shipping piping assembled (either in seperate sub-assemblies or on the machine) risks damage to the piping or the machine itself.

Line 10 “Electronic Vibration Test Data” An electronic copy of the vibration test data may be useful for future reference. A format that will be usable in future years should be mutually agreed upon.

E.10.1 Generator Data

This data, plus that on pages 8 and 9 gives technical details of the generator and is to be filled in by the machine vendor with the proposal or after the order.

E.11 Page 8

Line 17 “Provide Generator Preliminary Parameters with Proposal” The generator basic rating data listed here is necessary for preliminary power system calculations. Since these preliminary calculations are normally required, they are normally necessary.

E.12 Page 10

E.12.1 Analysis, Shop Inspection, and Tests

Line 7 “Acceptance Criteria” This section of the data sheet is used to indicate the analyses, inspections, and testing that are required during the manufacturing, assembly, and final testing of the machine. The number of procedures that are required may have a significant impact on the price and quality of the final machine. Required tests may be “Witnessed” or “Observed.” For a definition of these terms, refer to API 546, 4.1.3.

Line 8 “Coordination Meeting” A coordination meeting is useful at the start of the project to ensure that the vendors understand the scope and intent of the project, and that the generator vendor knows what will be required of the generator. In addition, the purchaser will learn of any general vendor concerns about the application.

Line 9 “Design Review” This is a comprehensive review meeting where the detailed electrical and mechanical designs are discussed and any electrical/mechanical analyses are presented. This is recommended for critical generators ratings above 3000 kVA, or for new manufacturer designs (prototypes). This meeting is not the “order coordination meeting.” The purchaser and vendor representatives meet after preliminary engineering is complete (normally 4–6 weeks after placement of order) to review designs and coordination with other associated equipment. The review includes but is not necessarily limited to the following topics:

a) performance curves;

b) excitation requirement;

c) allowable temperatures of rotor parts;

d) method of efficiency determination and guarantee of efficiency;

e) inertia of the machine and coupled equipment;

f) stator winding and winding insulation system;

g) rotor winding, mechanical design, fits, construction,balance;

h) shaft design stress, short circuit torques;

i) torsional and lateral critical speed analysis and rotor sensitivity analysis (response to an intentional unbalance);

j) foundation and base stiffness;

k) coupling type and coordination;

l) bearing details;

m) bearing and coupling insulation;

n) lubricating oil type and oil inlet temperature range;

o) API 546 compliance;

p) “witness” and “observe” points for inspections and tests;

q) test agenda; and

r) data for performance of electrical power system studies by the purchaser.

Topics may be added and subtracted as needed.

Line 10 “Torsional Analysis” This is normally done by the driver manufacturer, but could also be verified by the generator manufacturer or a third party. This analysis is usually performed only on systems with gearboxes.

Line 11 “Lateral Critical Speed Analysis” This analysis is usually done by the generator manufacturer and gives the system “critical speeds" of the rotor, bearing, bearing support, and foundation system. A critical speed is usually excited by rotor unbalances or misalignment. It is important to predict where the critical speeds are and how the rotor will react to excitations that can result in lateral shaft vibration. This analysis is recommended for two-pole machines 800 kVA and larger, or for four-pole machines 5000 kVA or larger. Most other ratings operate well below the first critical speed.

Line 12 “Review of Quality Control Program” This would normally be specified when a new supplier has been specified and the purchaser would like to review documentation of the vendor’s quality assurance program.

Line 13 “Submit Test Procedures 6 Weeks before Tests” This is specified when the purchaser wants time to review the proposed test routine and clarify what is to be done.

Line 14 “Inspection for Cleanliness per API 614” Requires the lube-oil system cleanliness of API Std 614. Specify when the special-purpose API 614 lube-oil system is supplied by the generator manufacturer.

Line 15—"Observance of Assembly/Dismantling"—Specify if the purchaser wishes to reserve the right to observe the testing, dismantling, inspection and reassembly of the generator. Normally this should be specified and most suppliers do not impose a charge for a purchaser to retain this right.

Line 16—"Demonstrate Accuracy of Test Equipment"—The generator supplier should have this documented every 6 months to 1 year and should be able to supply this documentation on request. If the test setup is unique or if the generator supplier does not have the accuracy documented, you may wish to specify this.

Line 17—"Stator Core Test"—A quality test for core plate insulation integrity or damage. Some suppliers do this test during manufacturing, but should only be specified by the user for unspared machines or applications where the machine will be inaccessible for easy repair or replacement.

Line 18—"Surge Comparison Test"—This is recommended. The risk of not doing the test is that marginal turn-to-turn insulation in the winding may not fail during the running tests but may fail in operation when subjected to mild power system surges. The test voltage should be agreed upon with the vendor, as too high a test voltage may induce premature failure. Machines over about 30 MVA may have “Roebel" stator bars which do not require surge tests

Line 19 “Special Surge Test of Coils” Recommended for windings rated 6600 V and above, usually as an “observe."

Line 20 “Sacrificial Coils Cut Into Segments” he/she sacrificial coils made for the special surge test can be cut into segments after the surge test so that they may be inspected for voids in the insulation. Thickness of groundwall insulation can also be checked at this time. Machines with terminal voltages over 4160 Volts are subject to partial discharge deterioration if there are excessive void numbers or dimensions. The acceptability criteria are difficult to define but should be worked out before the tests. Segments should be examined from both the slot (straight) section and the end turn section.

Line 22 “Partial Discharge Test” A way to detect possible future partial discharge problems with insulation is to perform an off line partial discharge test on the motors in the factory. Amplitudes and phase relationships can be used to find where the possible problems exist. Acceptable levels vary between systems and should be derived in discussion with the vendor. Significant deviation between phases, or between similar machines, should be investigated. System partial discharge performance often improves in the first few months of operation.

Line 23 “Balance in a Minimum of 3 Planes” Recommended for machines operating in the flexible shaft mode.

Line 24 “Dynamic Balance Rotors 600 rpm and Above” This is a relatively low cost option and will give improved long term performance. It is recommended and is the default selection.

Line 25 “Final Balance” A final balance is required if the rotor has not been component balanced.

Line 26 “Component Balance > 4-Pole” Specify this on slower speed machines only if vibration is expected to be a concern. 2-pole and 4-pole generators are component balanced, meaning the basic rotor and shaft assembly is first balanced, then as components such as fans are added, and further balance correction is only to be performed on that component. This only adds correction where the unbalance is located, and makes rebalancing simpler.

Line 27 “Residual Unbalance Verification Test” This balance verification procedure is recommended for generators with 2 or 4 poles, and for six pole generators above 3000 kVa. This test is not necessary for generators having eight poles or more.

Line 28 “Balance Check with Half-coupling” Usually warranted only for two-pole generators of large size (2000 kVa and above) to determine the effects of mounting the coupling on the balance of the rotor. This is done in the same time frame and using the same procedures as the residual unbalance test. Check “required" when this is to be done.

Line 29 “Running Tests with Coupling Half” This is recommended for all 2-pole machines and those 4-pole machines operating above their first critical speed.

Line 30 “Stator Inspection Prior to Vacuum Pressure Impregnation” This is a physical inspection of the iron core of the generator and the winding insulation taping before the winding is put through vacuum pressure impregnation (VPI), a procedure to seal and solidify the winding insulation system. This inspection should be specified for very critical, unspared generators or for generators with voltage ratings 6600 V and above. Since this is a qualitative inspection it should be “witnessed,” when specified.

Line 31 “Sealed Winding Conformance” This test involves submersing the generator winding or spraying it with a wetting solution to verify the seal of the insulation system. This test may be applied to critical generators, those whose windings will be exposed to weather or wash down conditions and when purchasing from an unfamiliar supplier. This test should be as a “witness,” because corrective measures, in the event of a failure, require purchaser involvement.

Line 32 “Power Factor Tip-up Test” Recommended for stator voltages 6600 V and above for the completed stator. This test provides a “base line" for later maintenance tests to detect corona discharge within the insulation system. This test may also be specified on sacrificial coils for development testing, but acceptance criteria needs to be agreed upon between the user and supplier. The power factor tip up test is usually conducted at 10 % and 110 % or 20 % and 120 % of rated line-to-ground power voltage. The test results are plotted for each machine and percent deviation is calculated. When multiple generators of the same design are tested and compared, the test values should be similar. Any machine that deviates significantly from the others should be investigated further for any potential winding/ insulation problem(s).

Line 33 “Routine Test” This is the test that the manufacturer does as a minimum, to meet the NEMA or equivalent requirements. This will usually be done as part of the more extensive tests.

Line 34 “Insulation Resistance Using Table 7 Values” These voltage levels are recommended.

Line 35 “Bearing Dimensional and Alignment Checks before Tests” This is recommended for all machines. Records are made of bearing fits and clearances. In addition, a bearing disassembly and inspection is required at the completion of the running tests.

Line 36 “Bearing Dimensional and Alignment Checks after Tests” This item supplements the normal bearing inspection of 4.3.2.1.j and is recommended for two pole machines operating above their first mechanical-system resonance (“critical speed”) to assure the bearings have had no distress as the rotor speed passed through the resonance. Also recommended for designs where the mechanical performance is sensitive to small changes in bearing clearances.

Line 37 “Vibration Monitoring and Recording” Evaluate the vendor’s proposed data-acquisition system for vibration tests. Very useful and should be used for machines which will undergo unbalance-response tests. This requirement primarily applies to two-pole generators 1000 kVA and above, but may also be applicable to slower-speed generators of ratings above 3000 kVA. This is standard practice for many manufacturers. Use of a recording system actually saves the manufacturer test-floor time, since an unbalanced-response test, which takes up to 30 min for each “coast down,” need only be done once and the data accessed rather than being done four times (once for each shaft vibration probe).

Lines 38 to 44 “Complete Test” Imposes the API 546 “Complete Test” requirements, which are common for large or critical service machines and two-pole units. Specify this when the efficiency and temperature rise is to be determined. This test should be specified for at least one (generally the first) of each machine rating when multiple units are ordered at the same time. It should also be specified where the Efficiency Factor (EF) justifies the test cost to prove the efficiency.

Line 44 “Sound Pressure Level Test” This test should be done to establish a base line and to assist in solving problems for any noise sensitive situations.

E.13 Page 11

Line 8 “DC High-Potential Test” The generator will already have had a final AC high-potential test for a one minute duration to prove the insulation of the generator. Subsequent high-potential tests in the field will most likely be DC tests. If a base-line DC test is desired to compare with tests in the field, specify here. This test is performed at approximately 75 % of the equivalent final AC high-potential test, so it does relatively little damage to the insulation at this stress level.

Lines 9 to 10 “Rated Rotor Temperature Vibration Test” Specify this if the generator is not going to have a complete API test but it is still important to know that it is thermally stable.

Line 11 “Unbalance Response Test” Recommended for all two-pole machines 1000 kVA and larger and all four-pole machines 5000 kVA and larger to verify their performance operating through its first resonant speed, or to verify the location of its resonant speed above operating speed.

Line 12 “Bearing Housing Natural Frequency Test” Normally specified for the first generator manufactured of a certain frame size, or a uniquely designed generator. The risk of not requiring the test is low due to the low bearing housing vibration limits required by API 546, and if the generator passes the vibration tests, it probably does not have a significant resonance.

Line 13 “Certification of Materials” Upon request the vendor shall provide certification of material such as mill reports for major castings, forgings, shaft material, and the results of any positive material identification (PMI) requirements.

Line 14 “Final Assembly Running Clearances” This is recommended for critical machines.

Lines 15 to 20 “Material Inspection” A list must be attached which specifies the parts to be examined and the types of examinations to be done. For important machines the following material inspections are typical.

a) Welded Shafts—liquid penetrant, magnetic particle, hardness.

b) Forged Shafts—ultrasonic inspection.

c) Welded Fans—liquid penetrant and magnetic particle.

d) Cast Fans—radiography.

e) Bearing Babbitt—ultrasonic.

f) Lifting lugs—liquid penetrant and magnetic particle.

Line 21 “Certified Data Prior to a release for Shipment” Specified for critical machines when the test data must be submitted by the vendor and reviewed prior to release for shipment.

Line 22 "Burn-in Testing of Rotating Element Mounted Electronic Components" To improve the reliability of the excitation system rotating electronics a burn in test can be done to reduce the risk of "infant mortality" or inadequately designed systems causing premature excitation failures.

Line 23 "Heat Exchanger Performance Verification" This test confirms that water-to-air, or air-to-air heat exchanger has sufficient capacity to cool the air entering the machine. An inadequate heat exchanger will restrict the performance of the generator. Details of the test should be worked out between the parties involved.

Line 24 "Other" Examples of other analysis, inspection, or tests that might be specified are as follows.

(Analysis)—Indicate other analyses to be done by the generator or prime mover equipment manufacturer.

(Tests)—These tests are normally "witnessed" if done at the same time as other tests. Specify as applicable.

a) "Cooler Hydrotest"—Applies water at 150 % design pressure to the cooler to make sure it does not leak. Only specify for generators with water coolers (TEWAC). Usually specified as "required" or "observed" with the test done at the cooler manufacturing site.

b) "Leak detector"—Verifies the detector works when water is present. A simple test to be specified for TEWAC generators only.

c) "Air Filter DP Switch"—This test for proper operation of the air filter differential-pressure (DP) switch should be made when the DP switch is specified on weather protected generators

d) "Reed Critical Frequency"—Only applicable to the rare vertical generator applications A test to verify the mechanical resonance of the structure, which acts as a vibrating 'reed." A test in the generator manufacturer's factory only confirms the calculated value for the generator by itself. Considering the expense of this test, it is not specified often. It is a more meaningful test if the generator is mounted to the actual driver head and the test performed on the assembled generator and turbine in the turbine manufacturer's shop. Reed resonances should be at least 15 % separated from running-speed frequency excitation for the assembled generator and driver.

e) "Inspection of Equipment Lube-oil Piping"—Applied when a machine with a forced-lubrication system has a thorough inspection program. Recommended for forced lubricated bearings where a thorough flush of the equipment lube-oil piping will not be made at the installation site.

Annex F

Procedure for Determination of Residual Unbalance

F.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.

F.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-mm (oz-in.).

F.3 Maximum Allowable Residual Unbalance

F.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.

F.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 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. In the example problem, the left plane has a journal weight of 530.7 kg (1170 lb). The right plane has a journal weight of 571.5 kg (1260 lb).

F.4 Residual Unbalance Check

F.4.1 General

F.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.

F.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 degrees apart), each at the same radius (i.e. same moment). 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 F.4.2.

F.4.2 Procedure

F.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 488.4 g-mm (0.68 oz-in.), the trial weight should cause 488.4 g-mmto 976.8 g-mm (0.682 oz-in.to 1.36 oz-in.) of unbalance]. This trial weight and radius must be sufficient so that the resulting plot in F.4.2.5 encompasses the origin of the polar plot.

F.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.

F.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.

F.4.2.4 Remove the trial weight and rotate the trial weight to the next trial position (that is, 60, 120, 180, 240, 300 and 360 degrees 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.

F.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 work sheets, Figure F.3 and Figure F.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 work sheets are Figure F.1 and Figure F.2.

F.4.2.6 Repeat the steps described in F.4.2.1 through F.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.

F.4.2.7 For stacked component balanced rotors, a residual unbalance check shall be performed after initial balancing of the basic rotor including windings, after the addition of the next 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:

$$\text{Umax} = \frac{(6350) \times (W)}{(N)} = \frac{(6350) \times [\ \ ]}{[\ \ ]} = [\ \ ] \text{ (g-mm)}$$

Customary Units:

$$\text{Umax} = \frac{(4) \times (W)}{(N)} = \frac{(4) \times [\ \ ]}{[\ \ ]} = [\ \ ] \text{ (oz-in)}$$

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 [ ] is [ ] (g-mm)
Customary units: [ ] to [ ] is [ ] (oz-in)

Calculate the trial weight (TW):

$$\text{Trial Weight (TW)} = \frac{\text{Umax}}{\text{R}} = \frac{[\ \ ] \text{ g-mm}}{[\ \ ] \text{ mm}} = [\ \ ] \text{ (g)} \quad \text{or} \quad \frac{[\ \ ] \text{ oz-in}}{[\ \ ] \text{ in}} = [\ \ ] \text{ (oz)}$$

Conversion Information:

1kg = 2.2046 lbs   1 ounce = 28.345 grams   1 inch = 25.4 mm

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	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 F-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 F-2), determine the Y and Z values required for the residual unbalance calculation.

Step 5: Using the worksheet, (Figure F-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:

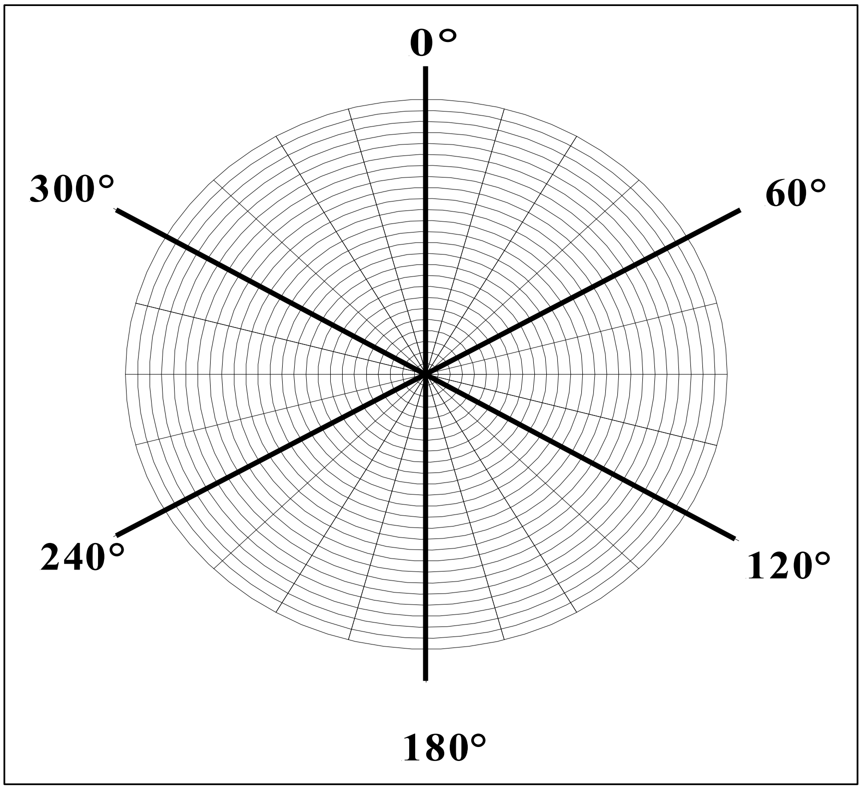
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the 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 F.1—(Blank) Residual Unbalance Work Sheet

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)**

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☐ **CCW** ☐ **CW**   **Phase is layed out:** ☐ **CCW** ☐ **CW**

Calculate Y and Z values:
Calculate Y and Z values:

Maximum amplitude value is:	☐		**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**	☐	**/**	☐	**=**	☐	**g-mm**
Customary Units:	☐	**X**	☐	**/**	☐	**=**	☐	**oz-in**

Allowable Unbalance Tolerance = Umax = ☐ **g-mm** ☐ **oz-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 F.2—(Blank) Residual Unbalance Polar Plot Work Sheet

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:

Umax = (6350) X (W) / (N) = (6350) X 530.7 / 6900 = 488.4 (g-mm)

Customary Units:

Umax = (4) X (W) / (N) = (4) X 1170 / 6900 = 0.7 (oz-in)

Calculate the trial unbalance (TU):

	(1 X)	to	(2 X)	(Selected Multiplier is)	1.6	
Trial Unbalance (TU) is between (1 X Umax) and (2 X Umax)						
SI Units:	**488.4**	**to**	**976.8**	**is**	**781.4**	**(g-mm)**
Customary units:	**0.7**	**to**	**1.4**	**is**	**1.1**	**(oz-in)**

Calculate the trial weight (TW):

Trial Weight (TW) = Umax / R = 781 g-mm / 381 mm = 2.1 (g) or 1.1 oz-in / 15 in = 0.07 (oz)

Conversion Information:

1kg = 2.2046 lbs   1 ounce = 28.345 grams   1 inch = 25.4 mm

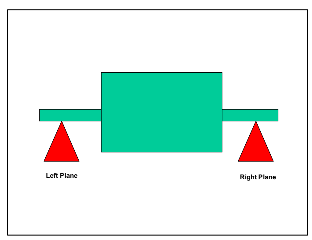
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout: Amplitude	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 F-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 F-2), determine the Y and Z values required for the residual unbalance calculation.

Step 5: Using the worksheet, (Figure F-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.

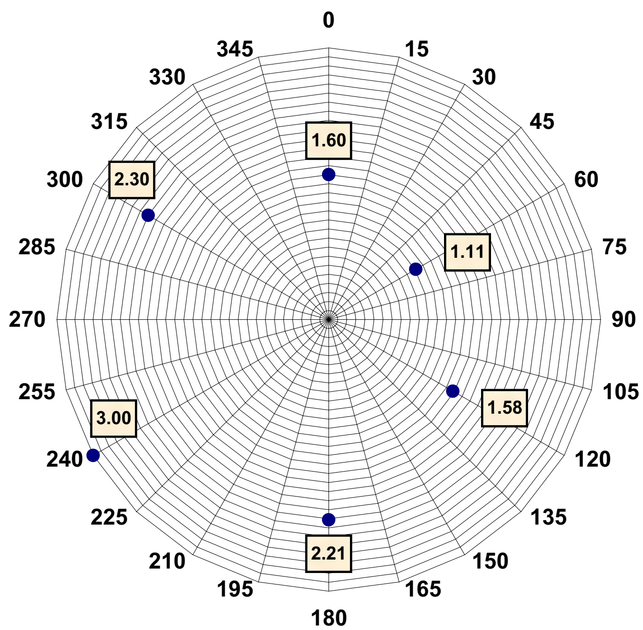
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	Date:	5/24/2000
Approved By:	CC	Date:	5/24/2000

Figure F.3—Sample Residual Unbalance Work Sheet 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		**Minimum amplitude value is:**			1.11
Y = (Maximum - Minimum) / 2 (	3.00	-	1.11	) / 2	=	0.95
Z = (Maximum + Minimum) / 2 (	3.00	+	1.11	) / 2	=	2.06

Residual Unbalance

Left in Rotor =	**(TU)**	**X**	**(Y)**	**/**	**(Z)**			
SI Units:	781	X	0.95	/	2.06	=	359.3	g-mm
Customary Units:	1.09	X	0.95	/	2.06	=	0.50	oz-in

Allowable Unbalance Tolerance = Umax = 488.4 **g-mm** 0.68 **oz-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 F.4—Sample Residual Unbalance Polar Plot Work Sheet 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:

Umax = (6350) X (W) / (N) = (6350) X 571.5 / 6900 = 525.9 (g-mm)

Customary Units:

Umax = (4) X (W) / (N) = (4) X 1260 / 6900 = 0.7 (oz-in)

Calculate the trial unbalance (TU):

Trial Unbalance (TU) is between (1 X Umax) and (2 X Umax) (Selected Multiplier is) **1.6**

	(1 X)		(2 X)			
SI Units:	525.9	to	1051.9	is	841.5	(g-mm)
Customary units:	0.7	to	1.5	is	1.2	(oz-in)

Calculate the trial weight (TW):

Trial Weight (TW) = Umax / R =

842	g-mm	or 1.17	oz-in
203	mm	8	in
4.1	(g)	0.15	(oz)

Conversion Information:

1kg = 2.2046 lbs   1 ounce = 28.345 grams   1 inch = 25.4 mm

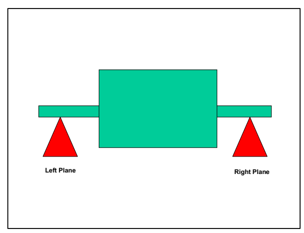
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout Amplitude	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 F-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 F-2), determine the Y and Z values required for the residual unbalance calculation.

Step 5: Using the worksheet, (Figure F-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.

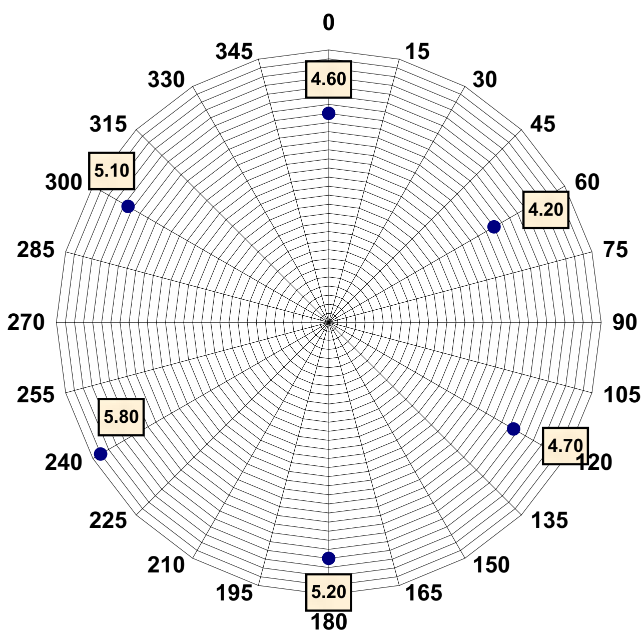
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	Date:	5/24/2000
Approved By:	CC	Date:	5/24/2000

Figure F.5—Sample Residual Unbalance Work Sheet 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		**Minimum amplitude value is:**				4.20
Y = (Maximum - Minimum) / 2 (	5.80	-	4.20	)	/ 2	=	0.80
Z = (Maximum + Minimum) / 2 (	5.80	+	4.20	)	/ 2	=	5.00

Residual Unbalance Left in Rotor =	(TU)	X	(Y)	/	(Z)			
SI Units:	781	X	0.80	/	5.00	=	125.0	g-mm
Customary Units:	1.09	X	0.80	/	5.00	=	0.17	oz-in

Allowable Unbalance Tolerance = Umax = 525.9 g-mm 0.68 oz-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 F.6—Sample Residual Unbalance Polar Plot Work Sheet for Right Plane

Annex G

Procedure and Guidance for Determining the Allowable Resultant Vector Change During a Heat Run Test of a Synchronous Machine

The purpose of this procedure is to verify that the rotor has minimal movement of the winding, laminations, rotor end rings, etc. Some small amount of change in vibration will always occur because of the movement of the rotor components when the rotor is heated from cold to the running condition.

This procedure is used to verify that the amount of movement of the rotor components is acceptable and repeatable. It also describes further tests that can be performed, at the purchasers' option, to establish repeatability, when the motor does not meet the requirements. Other methods are available to demonstrate thermal stability and must be agreed to by the purchaser prior to accepting the motor.

Vectors are used to represent the amount of vibration that this procedure describes. A vector is a measure of a quantity that has both magnitude and direction or phase angle. In vibration analysis, vectors are used to represent vibration quantities and their relative location, expressed in degrees, with respect to a reference point on the shaft that supports the rotor. The point of reference for the vector orientation is usually the keyway or another fixed point on the shaft such as reflective tape.

In each of the polar plots shown below the arrow of the cold vibration vector represents the starting point and magnitude of the vibration vector at the beginning of the heat run test. The cold point is achieved when the bearing temperature has stabilized at the no load condition. The arrow of the hot vibration vector represents the end of the heat run test. The resultant vector represents the change from the cold vibration to hot vibration.

The vibration vectors in the following figures are filtered at one times running speed and represent the fundamental frequency of vibration.

The vibration vectors are represented using a polar plot format. In such a format the angle of displacement from the reference point on the shaft starts at zero degrees in the first quadrant and encompasses 360 degrees in the counter clockwise direction. The magnitude of the vector starts at zero at the origin of the plot and increases as the vector length increase from the origin.

This procedure can only be used when the motor is tested with non-contact radial vibration probes.

A plot for each probe must be performed to verify that compliance with this Specification has been achieved.

The maximum amount of vibration that is allowed is 1.6 mils because this is the maximum allowable vibration displacement filtered at running speed frequency. See Figures 2, 3, 4, and 5 for more information.

All of the following examples are presented with the vibration vectors in the first and second quadrant of the polar plot for purpose of explanation only. In practical applications, the vibration vectors may be in any quadrant, and providing the values are acceptable, compliance with the requirement has been achieved.

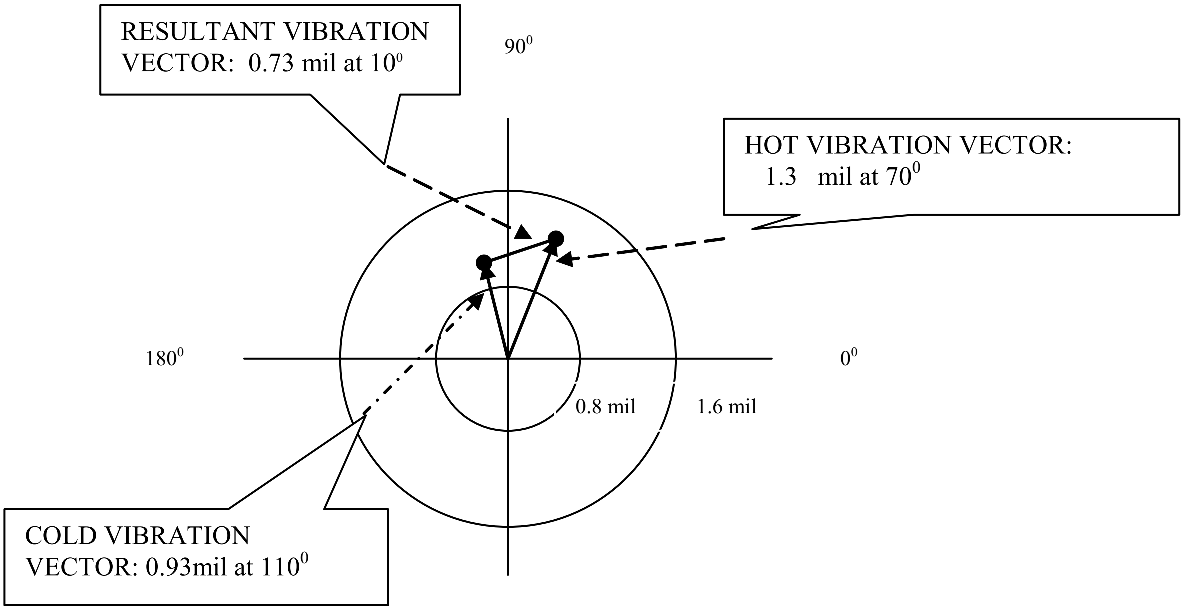


Figure G.1—Example of a Polar Plot of the Relationship of Cold to Hot Vibration Complying with the Requirements of 4.3.3.11 (This Example is Acceptable Because the Vibration is Always Less Than 1.6 mil and the Resultant Vector Change is Less Than 0.8 mil)

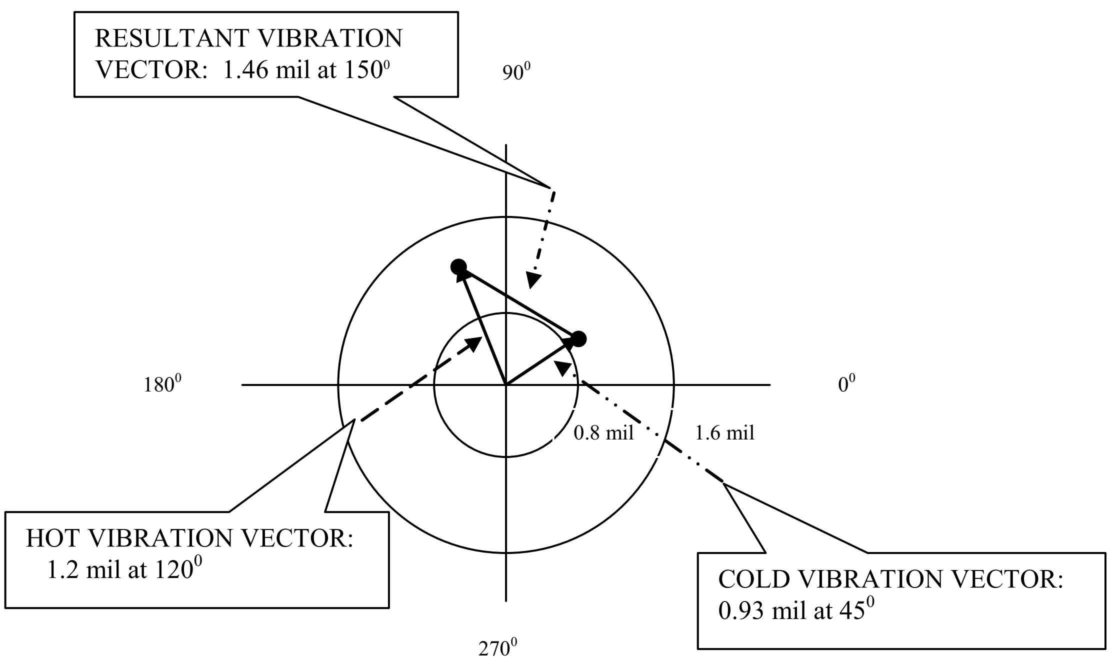


Figure G.2—Example of a Polar Plot of the Relationship of Cold to Hot Vibration Not Complying with the Requirements of 4.3.3.11 (This Example Demonstrates Lack of Compliance because the Resultant Vector Change of 1.46 Mils Exceeds the 0.8 Mil Limit)

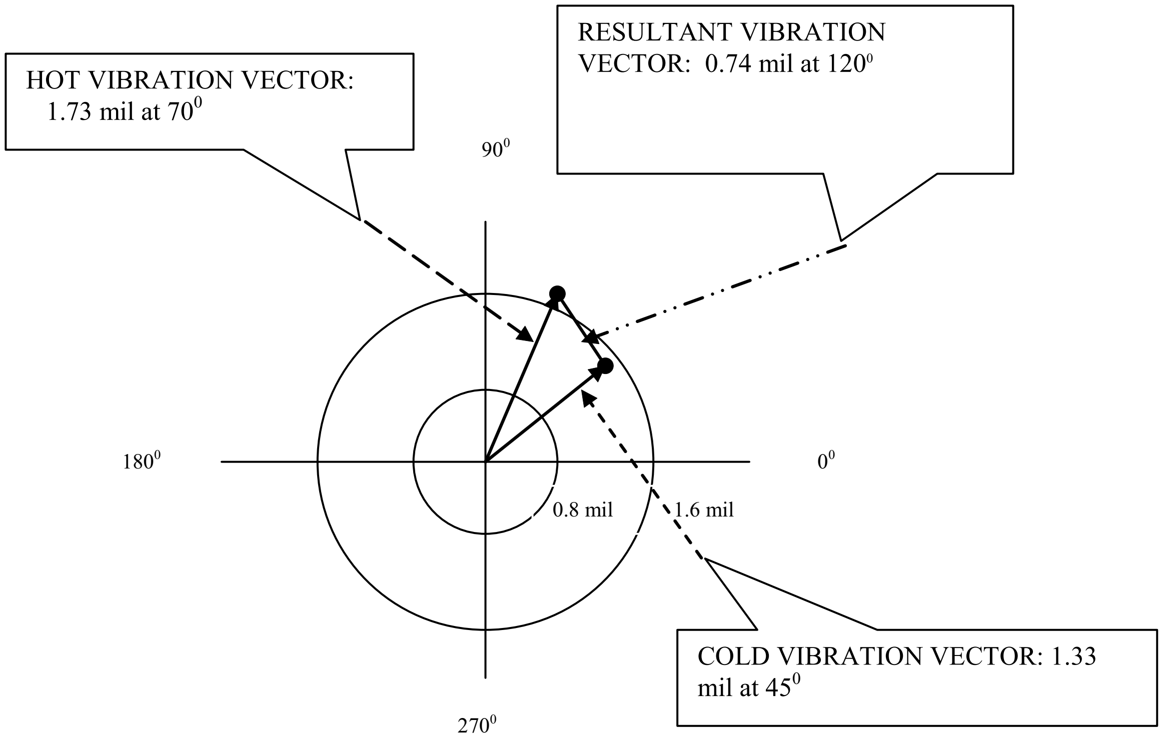


Figure G.3—Example of a Polar Plot of the Relationship of Cold to Hot Vibration Not Complying with the Requirements of 4.3.3.11 (This Example Does not Comply Because the 1.73 Mil Hot Vector Exceeds the 1.6 Mil Limit)

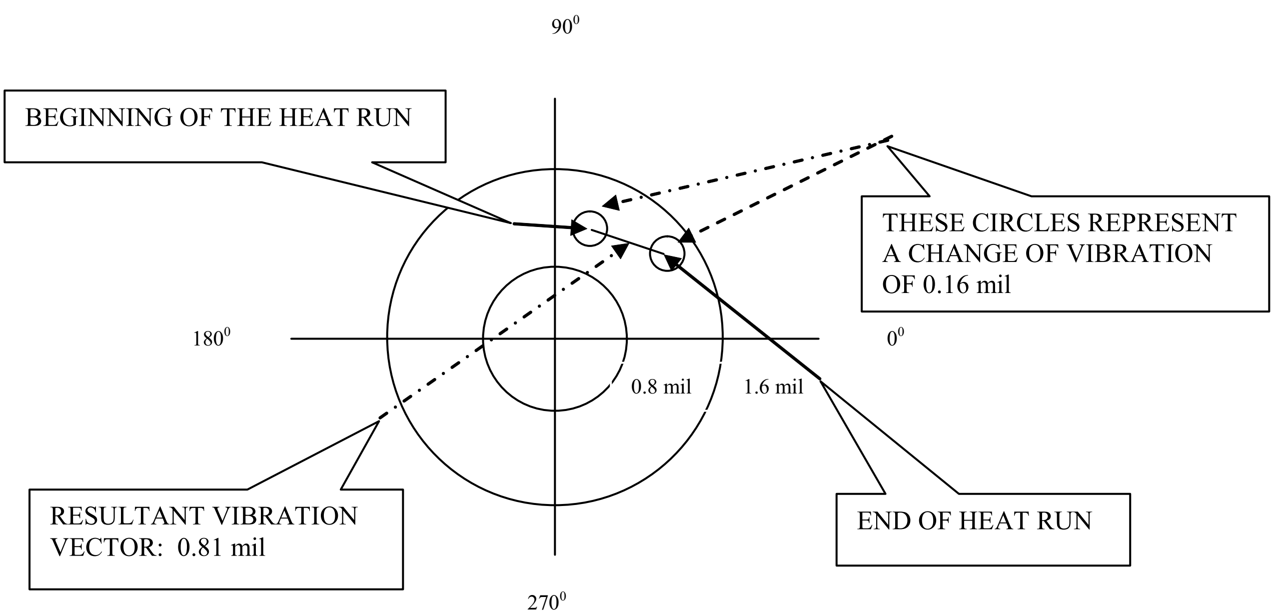


Figure G.4—Optional Criterion

This figure represents a possible option that may be used if a motor fails the basic specification criteria of a change larger than 0.8 mil but has a repeatable thermally stable rotor. The circles represent the maximum limits of allowable deviation between heat runs. The maximum recommended vibration change is 1.12 mil, which is twice the maximum allowable deviation plus the allowable thermal excursion. This example represents a vibration change exceeding the 0.8 mil limit. A higher level of vibration change may be considered with the purchasers' approval. In this example, circles of 0.16 mil radius are shown around the cold and hot vibration points from the first vibration tests. A second heat run test can be performed and if the cold and hot vibration vector endpoints from the second test fall within the 0.16 mil circles the rotor can be considered to be stable. In this example, the maximum vibration vector change from cold to hot in the repeated heat run can be as much as 1.13 mil, which is the 0.16 mil maximum allowable deviation each for the cold run and the hot run plus the 0.81 mil thermal excursion.

Annex H

Alternate Procedure for the Determination of a Well Damped Resonance

The material in this annex provides an alternate procedure for the determination of a well damped resonance to that outlined in paragraph 4.3.5.3. The material presented in this annex follows the Standard Paragraphs (SP) of the API CRE Subcommittee on Mechanical Equipment, Rev 22. Additional clarifications to the SP can be found in API 684 (*Tutorial on the API Standard Paragraphs Covering Rotor Dynamics and Balancing: An Introduction to Lateral Critical and Train Torsional Analysis and Rotor Balancing*).

H.1 Definition Of Terms

H.1.1
amplification factor
AF
a measure of a rotor bearing system's vibration sensitivity to unbalance when operating in the vicinity of one of its lateral critical speeds. A high amplification factor (AF > 10) indicates that rotor vibration during operation near a critical speed could be considerable and that critical clearance components may rub stationary elements during periods of high vibration. A low amplification factor (AF < 5) indicates that the system is not sensitive to unbalance when operating in the vicinity of the associated critical speed. Examples of the effect of the amplification factor on rotor response near the associated critical speed is presented in Figure F.1. The method of calculating the amplification factor from damped response calculation or vibration measurements is also presented in this figure. This calculation method is referred to as the half-power point method.

H.1.2
bode plot
a graphical display of a rotor's synchronous vibration amplitude and phase angle as a function of shaft rotational speed. A Bode Plot is the typical result of a rotor damped unbalance response analysis and/or shop test data.

H.1.3
critical speed
is the shaft rotational speed that corresponds to a non-critically damped (AF > 2.5) rotor system resonance frequency. The frequency location of the critical speed is defined as the frequency of the peak vibration response as defined by the Bode plot, resulting from a damped unbalanced response analysis and shop test data.

H.1.4
damping
a property of a dynamic system by which mechanical energy is removed. Damping is important in controlling rotor vibration characteristics and is usually provided by viscous dissipation in fluid film bearings, floating ring oil seals, and so forth.

H.1.5
phase angle
the angular distance between a shaft reference mark and the maximum shaft displacement measured by a fixed displacement transducer during one shaft rotation. The phase angle is useful in determining unbalance orientation, critical speed locations, and the amplification factors associated with critical speeds.

H.1.6
resonance (natural frequency)
the manner in which a rotor vibrates when the frequency of the harmonic (periodic) forcing function coincides with a natural frequency of the rotor system. When a rotor system operates in a state of resonance, the forced vibrations from a given exiting mechanism (such as unbalance) are amplified according to the level of damping present in the system. A resonance is typically identified by a substantial vibration amplitude increase and shift in the phase angle.

H.1.7
sensitivity to unbalance
is a measure of the vibration amplitude per unit of unbalance.

H.1.8
separation margin
defines how close the operating speed of a machine may be to its critical speed. If a machine has a AF < 2.5, then by definition, this is not a critical speed and requires no separation margin.

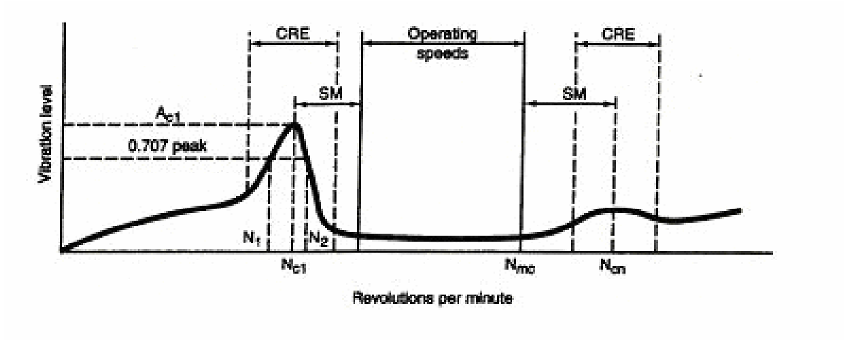
H.1.9
unbalance
is a measure that quantifies how much the rotor mass centerline is displaced from the centerline of rotation (geometric centerline) resulting in an unequal radial mass distribution on a rotor system. Unbalance is usually given in gram-mm or ounce-in.

H.1.10
undamped unbalance response analysis
a calculation of the rotor's response to a set of applied unbalances. This applied unbalance excites the rotor synchronously, so the rotor's response to unbalance will occur at the frequency of the shafts rotational speed. This analysis is used to predict critical speed characteristics of a machine. The analysis results are typically presented in Bode plots.

H.2 Comparison of Annex H to API 546, Paragraph 4.3.1.5.d

The main body of API 546 does not differentiate between a highly damped resonance and critical speed. As such, no method of calculating the amplification factor or separation margin is made.

Definitions H.1.1 through H.1.10 are based on the CRE API Standard paragraphs on mechanical equipment. According to the API standard paragraphs, these definitions consider modes of vibration with amplification factors below 2.5 to be critically damped. These modes are not considered critical speeds because they do not result in high levels of rotor vibration.



Nc1 = Rotor first resonant frequency, cycles per minute.
Ncn = Critical Speed, nth.
Nmc = Maximum continuous operating speed.
N1 = Initial (lesser) speed at 0.707 x peak amplitude.
N2 = Final (greater) speed at 0.707 x peak amplitude.
N2 -N1 = Peak width at the half power point.
AF = Amplification factor
SM = Separation margin.
CRE = Critical response envelope.
Ac1 = Amplitude at Nc1
Acn = Amplitude at Ncn

Figure H.1—Evaluation of Amplification Factor (AF) from Speed Amplitude Plots

energy API

2008 Publications Order Form

Effective January 1, 2008.
API Members receive a 30% discount where applicable.
The member discount does not apply to purchases made for the purpose of resale or for incorporation into commercial products, training courses, workshops, or other commercial enterprises.

Available through IHS:

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**
Online Orders: **global.ihs.com**

Date: ______________________

☐ **API Member** (Check if Yes)

Invoice To (☐ Check here if same as "Ship To")

Name:
Title:
Company:
Department:
Address:

City: State/Province:
Zip/Postal Code: Country:
Telephone:
Fax:
Email:

Ship To (UPS will not deliver to a P.O. Box)

Name:
Title:
Company:
Department:
Address:

City: State/Province:
Zip/Postal Code: Country:
Telephone:
Fax:
Email:

Quantity	Title	SO★	Unit Price	Total
	RP 500, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I Division 1 and Division 2		$191.00	
	RP 505, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1 and Zone 2		$191.00	
	RP 540, Electrical Installations in Petroleum Processing Plants		$176.00	
	Std 541, Form-wound Squirrel-cage Induction Motors-250 Horsepower and Larger		$161.00	
	Std 547, General-purpose Form-wound Squirrel Cage Induction Motors-250 Horsepower and Larger		$88.00	

☐ Payment Enclosed ☐ P.O. No. (Enclose Copy) ______

☐ Charge My IHS Account No. ______

☐ VISA ☐ MasterCard ☐ American Express
☐ Diners Club ☐ Discover

Credit Card No.:
Print Name (As It Appears on Card):
Expiration Date:
Signature:

Subtotal	
Applicable Sales Tax (see below)	
Rush Shipping Fee (see below)	
Shipping and Handling (see below)	
Total (in U.S. Dollars)	

★ To be placed on Standing Order for future editions of this publication, place a check mark in the SO column and sign here:

Pricing and availability subject to change without notice.

Mail Orders – Payment by check or money order in U.S. dollars is required except for established accounts. State and local taxes, $10 processing fee, and 5% shipping must be added. Send mail orders to: **API Publications, IHS, 15 Inverness Way East, c/o Retail Sales, Englewood, CO 80112-5776, USA.**

Purchase Orders – Purchase orders are accepted from established accounts. Invoice will include actual freight cost, a $10 processing fee, plus state and local taxes.

Telephone Orders – If ordering by telephone, a $10 processing fee and actual freight costs will be added to the order.

Sales Tax – All U.S. purchases must include applicable state and local sales tax. Customers claiming tax-exempt status must provide IHS with a copy of their exemption certificate.

Shipping (U.S. Orders) – Orders shipped within the U.S. are sent via traceable means. Most orders are shipped the same day. Subscription updates are sent by First-Class Mail. Other options, including next-day service, air service, and fax transmission are available at additional cost. Call 1-800-854-7179 for more information.

Shipping (International Orders) – Standard international shipping is by air express courier service. Subscription updates are sent by World Mail. Normal delivery is 3-4 days from shipping date.

Rush Shipping Fee – Next Day Delivery orders charge is $20 in addition to the carrier charges. Next Day Delivery orders must be placed by 2:00 p.m. MST to ensure overnight delivery.

Returns – All returns must be pre-approved by calling the IHS Customer Service Department at 1-800-624-3974 for information and assistance. There may be a 15% restocking fee. Special order items, electronic documents, and age-dated materials are non-returnable.

THERE'S MORE WHERE THIS CAME FROM.

API provides additional resources and programs to the oil and natural gas industry which are based on API Standards. For more information, contact:

API MONOGRAM® LICENSING PROGRAM
Phone: 202-962-4791
Fax: 202-682-8070
Email: certification@api.org

API QUALITY REGISTRAR (APIQR®)
> ISO 9001 Registration
> ISO/TS 29001 Registration
> ISO 14001 Registration
> API Spec Q1® Registration
Phone: 202-962-4791
Fax: 202-682-8070
Email: certification@api.org

API PERFORATOR DESIGN REGISTRATION PROGRAM
Phone: 202-682-8490
Fax: 202-682-8070
Email: perfdesign@api.org

API TRAINING PROVIDER CERTIFICATION PROGRAM (API TPCP™)
Phone: 202-682-8490
Fax: 202-682-8070
Email: tpcp@api.org

API INDIVIDUAL CERTIFICATION PROGRAMS (ICP®)
Phone: 202-682-8064
Fax: 202-682-8348
Email: icp@api.org

API ENGINE OIL LICENSING AND CERTIFICATION SYSTEM (EOLCS)
Phone: 202-682-8516
Fax: 202-962-4739
Email: eolcs@api.org

API PETROTEAM (TRAINING, EDUCATION AND MEETINGS)
Phone: 202-682-8195
Fax: 202-682-8222
Email: petroteam@api.org

API UNIVERSITY™
Phone: 202-682-8195
Fax: 202-682-8222
Email: training@api.org

Check out the API Publications, Programs, and Services Catalog online at www.api.org.

1220 L Street, NW
Washington, DC 20005-4070
USA

202.682.8000

Additional copies are available through IHS
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
Online Orders: global.ihs.com

Information about API Publications, Programs and Services
is available on the web at www.api.org

Product No. C54603