Axial and Centrifugal Compressors and Expander-compressors

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Axial and Centrifugal Compressors and Expander-compressors
Part 1—General Requirements

1 Scope

This standard specifies minimum requirements and gives recommendations for axial compressors, single-shaft and integrally geared process centrifugal compressors, and expander-compressors for special-purpose applications that handle gas or process air in the petroleum, chemical, and gas industries. This part of API 617 specifies general requirements applicable to all such machines.

API 617 does not apply to the following:

— fans (these are covered by API 673) or blowers that develop less than 34 kPa (5 psi) pressure rise above atmospheric pressure;

— integrally geared centrifugal plant and instrument air compressors, which are covered by API 672;

— axial inflow expanders, such as hot gas expanders.

This part of API 617 contains information pertinent to all equipment covered by the other parts of this document. It shall be used in conjunction with the following parts, as applicable to the specific equipment covered:

— *Part 2—Nonintegrally Geared Centrifugal and Axial Compressors*;

— *Part 3—Integrally Geared Centrifugal Compressors*;

— *Part 4—Expander-compressors.*

2 Normative References

2.1 The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 541, *Form-wound Squirrel Cage Induction Motors—375 kW (500 Horsepower) and Larger,* Fifth Edition

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

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

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

API Standard 614, *Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries*, Fifth Edition

API Standard 616, *Gas Turbines for the Petroleum, Chemical, and Gas Industry Services,* Fifth Edition

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

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

API Technical Report 684-1, *API Standard Paragraphs Rotordynamic Tutorial: Lateral Critical Speeds, Unbalance Response, Stability, Train Torsionals, and Rotor Balancing,* First Edition

API Recommended Practice 687, *Rotor Repair,* First Edition

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

API Recommended Practice 691, *Risk-based Machinery Management,* First Edition

API Standard 692, *Dry Gas Sealing Systems for Axial, Centrifugal, Rotary Screw Compressors and Expanders*, First Edition

ANSI [1]/AGMA ISO 1328-1-B14 [2], *Cylindrical Gears—ISO System of Flank Tolerance Classification—Part 1: Definitions and Allowable Values of Deviations Relevant to Flanks of Gear Teeth*

ANSI/AGMA 2101-C95, *Fundamental Rating Factors And Calculation Methods For Involute Spur And Helical Gear Teeth*

AGMA 2101-D04, *Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth*, 2004 (Reaffirmed 2010)

ASME B1.1-2003 (R2018) [3], *Unified Inch Screw Threads, UN and UNR Thread Form*

ASME B1.13M-2005 (R2020), *Metric Screw Threads: M Profile*

ASME B1.20.1-2013, *Pipe Threads, General Purpose (Inch)*

ASME B16.1-2015, *Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250*

ASME B16.5-2017, *Pipe Flanges and Flanged Fittings: NPS ½ Through NPS 24 Metric/Inch Standard*

ASME B16.11-2016*, Forged Fittings, Socket-Welding and Threaded*

ASME B16.42-2016, *Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300*

ASME B16.47-2017, *Large Diameter Steel Flanges: NPS 26 Through NPS 60 Metric/Inch Standard*

ASME *Boiler and Pressure Vessel Code (BPVC)*-2017, *Section V: Nondestructive Examination*

ASME *BPVC*-2017, *Section VIII, Division 1: Rules for Construction of Pressure Vessels*

ASME *BPVC*-2017, *Section IX: Welding, Brazing, and Fusing Qualifications—Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators*

ASME PTC 10-1997, *Performance Test Code on Compressors and Exhausters*

ASME PTC 36, *Measurement of Industrial Noise*

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1 American National Standards Institute, 1899 L. Street, NW, 11th Floor, Washington, DC 20036, www.ansi.org.

2 American Gear Manufacturers Association, 1001 North Fairfax Street, Suite 500, Alexandria, Virginia 22314, www.agma.org.

3 American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

ASTM A193/A193M [4], *Standard Specification for Alloy-Steel and Stainless Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*

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

ASTM A247, *Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings*

ASTM A278/A278M, *Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 °F (350 °C)*

ASTM A307, *Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rods 60 000 PSI Tensile Strength*

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

ASTM A395/A395M, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM A536, *Standard Specification for Ductile Iron Castings*

ASTM A563/A563M, *Standard Specification for Carbon and Alloy Steel Nuts (Inch and Metric)*

ASTM A578, *Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications*

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

ASTM E94/E94M, *Standard Guide for Radiographic Examination Using Industrial Radiographic Film*

ASTM E125-63 (2018), *Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings*

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Testing for General Industry*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

AWS D1.1/D1.1M:2015 [5], *Structural Welding Code—Steel*

DIN ISO 228-1[6], *Pipe threads where pressure-tight joints are not made on the threads—Part 1: Dimensions, tolerances and designation*

EN 1092-1:2007+A1:2013 [7], *Flanges and their joints—Circular flanges for pipes, valves, fittings and accessories, PN designated—Part 1: Steel flanges*

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

[5] American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166, www.aws.org.

[6] German Institute for Standardization, Burggrafenstraße 6, 10787 Berlin, Germany, www.din.de.

[7] European Committee for Standardization (CEN), Rue de la Science 23, B-1040 Brussels, Belgium, www.cen.eu.

EN 1092-2:1997, *Flanges and their joints—Circular flanges for pipes, valves, fittings and accessories, PN designated—Part 2: Cast iron flanges*

EN 55011:2016+A1:2017, *Industrial, scientific and medical (ISM) radio-frequency equipment—Electromagnetic disturbance characteristics—Limits and methods of measurement*

EN 61000-6-2:2005, *Electromagnetic compatibility (EMC)—Part 6-2: Generic standards—Immunity for industrial environments*

IEC 60079-10-1:2015 [8], *Explosive atmospheres—Part 10-1: Classification of areas—Explosive gas atmospheres*

IEC 60529:2013, *Degrees of protection provided by enclosures (IP Code)*

IEEE 841:2009 [9], *IEEE Standard for Petroleum and Chemical Industry—Premium-Efficiency, Severe-Duty, Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 370 kW (500 hp)*

ISPM 15:2009 [10], *Regulation of Wood Packaging Material in International Trade*

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

ISO 261, *ISO general-purpose metric screw threads—General plan*

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

ISO 3744, *Acoustics—Determination of sound power levels and sound energy levels of noise sources using sound pressure—Engineering methods for an essentially free field over a reflecting plane*

ISO 5389, *Turbocompressors—Performance test code*, Second Edition

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

ISO 8068, *Lubricants, industrial oils and related products (Class L) - Family T (Turbines) - Specification for lubricating oils for turbines*

ISO 8501, *Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness*

ISO 9606, Parts 1–6, *Qualification testing of welders—Fusion welding*

ISO 14839-1, *Mechanical vibration—Vibration of rotating machinery equipped with active magnetic bearings—Part 1: Vocabulary*

ISO 14839-3, *Mechanical vibration—Vibration of rotating machinery equipped with active magnetic bearings—Part 3: Evaluation of stability margin*

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[8] International Electrotechnical Commission, 3 rue de Varembé, CH-1211 Geneva 20, Switzerland, www.iec.ch.

[9] Institute of Electrical and Electronics Engineers, 3 Park Avenue, 17th Floor, New York, New York, 10016, www.ieee.org.

[10] Food and Agriculture Organization of the United Nations, International Plant Protection Convention, Viale delle Terme di Caracalla, 00153 Rome, Italy, http://www.fao.org/home/en.

[11] International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

ISO 15614-1:2017, *Specification and qualification of welding procedures for metallic materials—Welding procedure test—Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 21940-32:2012, *Mechanical vibration—Rotor balancing—Part 32: Shaft and fitment key convention*

NACE MR0103/ISO 17945 [12], *Petroleum, petrochemical and natural gas industries—Metallic materials resistant to sulfide stress cracking in corrosive petroleum refining environments*

NACE MR0175/ISO 15156, *Petroleum and natural gas industries—Materials for use in H_2S containing environments in oil and gas production*

NACE SP0472-2015, *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*

NEMA 250–2014 [13], *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NFPA 70:2017 [14], *National Electrical Code*

SAE J518-2013 [15], *Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flange Type*

SSPC SP 6:2007 [16], *Commercial Blast Cleaning*

2.2 [●] The hierarchy of documents shall be specified.

NOTE Typical documents submitted as a user inquiry or orders are user specifications, industry specifications (such as API and ISO specifications), datasheets, meeting notes, and supplemental agreements.

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

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

3.1.1
abradable seal
Seal design that anticipates rotor or rotor sleeve contact and possible stator element penetration maintaining acceptable sealing performance with no dimensional change to the labyrinth teeth.

NOTE An example of an abradable seal is rotating labyrinth teeth into a polytetrafluoroethylene (PTFE) stator strip.

3.1.2
anchor bolts

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[12] NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

[13] National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, Virginia 22209, www.nema.org.

[14] National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169, www.nfpa.org.

[15] SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, www.sae.org.

[16] Society for Protective Coatings (now the Association for Materials Protection and Performance), 800 Trumbull Drive, Pittsburgh, Pennsylvania 15205, www.sspc.org.

Bolts used to attach the soleplate or baseplate to the support structure (concrete foundation or steel structure); cf. “hold-down bolts” (see 3.1.15).

3.1.3
axially split joint
Casing joint split with the principal face parallel to the shaft centerline.

3.1.4
baseplate
skid
Fabricated steel structure designed to support the driven and/or driver equipment and other ancillaries that may be mounted upon it.

3.1.5
buffer gas
Clean gas supplied to the process side of a double seal that is used to keep untreated process gas away from the seal.

NOTE Buffer gas is not intended to flow through dry gas seal faces.

3.1.6
capacity limit
Highest flow point at which the performance curve terminates on a given speed line or guide vane angle.

3.1.7
cartridge bundle assembly (centrifugal)
Assembly consisting of the complete compressor assembly minus the casing.

NOTE It includes the inner barrel assembly, end heads, seals, bearing housings, and bearings. It also includes the rotor assembly. It is designed to be shop assembled and ready for insertion into the casing to minimize installation work in the field.

3.1.8
certified point
Point to which the performance tolerances will be applied.

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

3.1.9
complex stiffness
Notation for the total equivalent stiffness and damping expression, including the cross-coupled terms as required for the hydrodynamic bearing or squeeze damper oil film.

3.1.10
compliant seal
A stationary seal that deflects during a rotor rub, and then returns back to its original shape or position.

3.1.11
compressor section
Series of one or more impellers with defined external process conditions (e.g. side streams, bypassing).

3.1.12
critical speed
Shaft rotational speed at which the rotor-bearing support system is in a state of resonance.

3.1.13

design point
This is a term used by the equipment manufacturer to set various parameters such as power, pressure, temperature, or speed. It is not intended for the purchaser to define this point.

3.1.14
gear wheel
bull gear
Lowest speed rotor in a gearbox; cf. "pinion(s)" (see 3.1.39).

3.1.15
hold-down bolts
Bolts holding the equipment to the soleplate or baseplate; cf. "anchor bolts" (see 3.1.2).

3.1.16
hydrodynamic bearings
Bearings that incorporate a fluid film to form an oil wedge, or wedges, that support the load without shaft-to-bearing contact.

3.1.17
informative
Information only; cf. "normative" (see 3.1.37).

NOTE An informative reference or annex provides advisory or explanatory information. It is intended to assist the understanding or use of the document.

3.1.18
inlet volumetric flow
Flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility, and gas composition, including moisture content, at the inlet flange.

3.1.19
inner barrel assembly
Assembly consisting of the internal stationary parts that makes up the removable portion of the flow path, including the inner barrel, the diaphragms, the impeller eye labyrinths, and the diaphragm labyrinths.

3.1.20
internal friction
A potentially destabilizing damping force produced from the phase difference between the stress and strain in any material under cyclic loading.

3.1.21
low temperature service
Service where the specified minimum design metal temperature is below −29 °C (−20 °F).

3.1.22
maximum allowable working pressure
MAWP
Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) if handling the specified fluid at the specified maximum operating temperature.

3.1.23
maximum allowable working temperature
MAWT
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) if handling the specified fluid at the specified maximum allowable working pressure.

3.1.24
maximum continuous speed
Highest rotational speed (revolutions per minute) at which the machine, as-built and tested, is capable of continuous operation.

3.1.25
maximum inlet pressure
Highest specified inlet pressure the equipment shall be subject to.

3.1.26
maximum operating pressure
Highest continuous pressure expected for any specified operating condition over the entire operating performance map.

3.1.27
maximum operating temperature
Highest continuous temperature expected for any specified operating condition over the entire operating performance map.

3.1.28
maximum sealing pressure
Highest pressure the seals are required to seal during any specified operating conditions including start-up, shutdown, settle-out, and standby.

3.1.29
minimum allowable speed
Lowest speed (revolutions per minute) at which the manufacturer's design shall permit continuous operation.

3.1.30
minimum design metal temperature
Lowest mean metal temperature (through the thickness) expected in service, including operation upsets, auto refrigeration, and temperature of the surrounding environment for which the equipment is designed.

NOTE Adapted from the ASME *BPVC*.

3.1.31
modular rotor
Rotor that is built up using stub shafts or similar devices and held together by one or more through bolts.

3.1.32
moment simulator
Auxiliary device intended to create the moment of the mass of a half coupling.

NOTE A moment simulator can also be designated to serve as an idling adapter (solo plate).

3.1.33
nominal pipe size
NPS
Value approximately equal to a diameter in inches.

EXAMPLE NPS $^{3}/_{4}$.

NOTE 1 Adapted from ASME B31.3.

NOTE 2 The letters NPS are followed by a value that is related to an approximate diameter of the bore, in inches, for piping up to and including 12 in. diameter. For piping over 12 in. (NPS 12), the NPS value is the nominal OD.

3.1.34

nominal pressure
PN
Numerical designation relating to pressure that is a convenient round number for reference purposes.

EXAMPLE PN 100 (ISO 7268:1983).

NOTE The permissible working pressure associated with a PN designation depends upon materials, design, and working temperature and has to be selected from the pressure/temperature rating tables in corresponding standards.

3.1.35
normal operating point
Point at which usual operation is expected and optimum efficiency is desired.

NOTE This point is usually the point at which the vendor certifies that performance is within the tolerances stated in this standard.

3.1.36
normal speed
Speed corresponding to the requirements of the normal operating point.

3.1.37
normative
Required; cf. "informative" (see 3.1.17).

NOTE A normative reference or annex enumerates a requirement or mandate of the specification.

3.1.38
observed (tests and inspections)
Inspection or test where the purchaser is notified of the schedule and the inspection is performed as scheduled even if the purchaser or purchaser's representative is not present; cf. "witnessed (tests and inspections)" (see 3.1.72).

3.1.39
pinion(s)
High-speed rotor(s) in a gearbox; cf. "gear wheel" (see 3.1.14).

3.1.40
pressure casing
Composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts that isolates process gas from the atmosphere. Shaft end seals are not considered to be part of the pressure casing.

3.1.41
purchaser
Agency that issues the order and specification to the vendor.

3.1.42
radially split
Casing joint split with the principal face perpendicular to the shaft centerline.

3.1.43
rated point
Rated point is the intersection on the 100 % speed line corresponding to the highest flow of any specified operating point for centrifugal compressors; rated point will be determined by the vendor for axial compressors and centrifugal compressors with variable inlet guide vanes (VIGVs).

NOTE This is generally a derived point rather than an actual operating point (see Figure 1 for a graphical representation).

3.1.44
rated power
Power required at the rated point.

3.1.45
rated speed
100 % speed
Highest rotational speed (revolutions per minute) required to meet any specified operating conditions.

3.1.46
relief valve set pressure
Pressure at which a relief valve starts to lift.

3.1.47
separation gas
Air or inert gas used to isolate an atmospheric bearing housing from the seal housing.

3.1.48
service factor (gear)
Factor used in the gear rating calculations that is applied to the tooth pitting index and the bending stress number, depending upon the characteristics of the driver and the driven equipment, to account for differences in potential overload, shock load, and/or continuous oscillatory torque characteristics (see Part 3, Annex F).

3.1.49
settle-out pressure
Highest pressure that the compressor experiences while at standstill and equilibrium conditions.

NOTE Determination of settle-out pressure requires consideration of the trapped volume of gas throughout the compressor and its associated piping system.

3.1.50
shaft end seal
Process gas seal on the shaft that restricts leakage of process gas to the atmosphere.

3.1.51
shutdown
Condition as determined by the equipment user that requires action to stop the equipment; may be automated or manual.

3.1.52
slow roll
Speed less than 5 % of the normal operating speed or the minimum speed permitted by the speed control.

3.1.53
soleplate
A plate with a machined top surface that is grouted to a concrete foundation to support machinery.

3.1.54
special-purpose application
Application for which the equipment is designed for uninterrupted, continuous operation in critical service, and for which there is usually no installed spare equipment.

3.1.55
special tool
Tool that is not a commercially available catalogue item.

3.1.56
stability analysis
Determination of the natural frequencies and the corresponding logarithmic decrements (log decs) of the damped rotor/support system using a complex eigenvalue analysis.

3.1.57
standard volume flow
Flow rate expressed in volume flow units at one of the standard conditions below.

ISO standard (normal) conditions:

Flow:	normal cubic meters per hour (Nm^3/h)
	normal cubic meters per minute (Nm^3/min)
Pressure:	1.01325 bar absolute
Temperature:	0 °C
Humidity:	0 %
Compressibility factor:	0 °C and 1.01325 bar absolute

US customary standard conditions:

Flow:	standard cubic feet per minute (scfm)
	million standard cubic feet per day (mmscfd)
Pressure:	14.7 psia
Temperature:	60 °F
Humidity:	0 %
Compressibility factor:	60 °F and 14.7 psia

NOTE 1 There are no universally accepted conditions for normal or standard cubic meters; therefore, their reference pressure and temperature are always spelled out, i.e. m^3/h 0 °C, 1.013 bara.

NOTE 2 Due to the lack of uniformity on standard conditions, mass flow is typically provided in conjunction with standard flow rates to avoid confusion.

3.1.58
structure stiffness and damping
Bearing housing to ground equivalent complex stiffness.

3.1.59
subsoleplate
Separate plate/structure between the soleplate or baseplate and foundation/grout to provide levelling capability.

3.1.60
support stiffness
Equivalent oil film to ground complex stiffness characteristics; pivot stiffness is typically included in the oil film characteristics.

3.1.61
surge
surge limit
Flow instability that occurs in a centrifugal or axial compressor at low volumetric flow.

3.1.62
synchronous tilt pad coefficients
Complex frequency dependent coefficient with the frequency equal to the rotational speed of the shaft.

3.1.63
tooth pitting index
Corresponds to a contact surface stress number; the tooth pitting index is used to determine a load rating at which progressive pitting of the teeth does not occur during their design life.

3.1.64
total indicator runout
total indicator reading
TIR
runout
Difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

NOTE For a cylindrical surface, the indicated runout implies an eccentricity equal to half the reading. For a flat face, indicated runout implies an out-of-squareness equal to the reading.

3.1.65
trip
Automated shutdown to ensure personnel safety (safety critical).

3.1.66
trip speed
<electric motor driver>
Speed corresponding to the synchronous speed of the motor at maximum intended supply frequency at the motor terminals plus a 2 % margin.

3.1.67
trip speed
<turbine, engine, expander>
Speed at which the independent emergency overspeed device operates to shut down the driver.

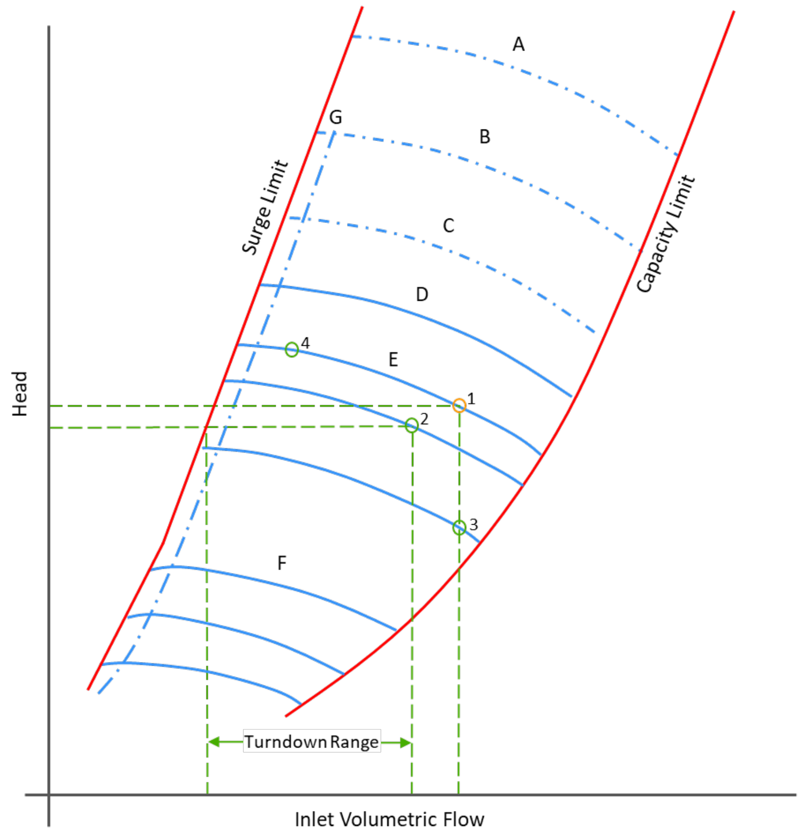
3.1.68
turndown
The difference between a specified operating point's capacity and surge capacity, divided by that specified capacity expressed as a percentage; for VIGV and variable-speed machines, the surge capacity shall be defined at that specified head (see Figure 1).

3.1.69
ultimate load rating (hydrodynamic thrust bearing)
Load that will produce the minimum acceptable oil film thickness without inducing failure during continuous service, or the load that will not exceed the creep initiation or yield strength of the babbitt or bearing material.

3.1.70
unit responsibility
Obligation for coordinating the documentation, delivery, and technical aspects of the equipment and all auxiliary systems included in the scope of the order.

3.1.71
vendor
Manufacturer or manufacturer's agent that supplies the equipment.

3.1.72
witnessed (tests and inspections)
Inspection or test where the purchaser is notified of the schedule and a hold is placed until the purchaser or the purchaser's representative is in attendance; cf. "observed (tests and inspections)" (see 3.1.38).



Key

A critical speed

B trip speed steam turbine drive

C trip speed gas turbine drive

D maximum continuous speed (N_{mc}) variable-speed drive

E rated (100 %) speed

F minimum operating speed

G anti-surge control line

1 compressor rated point

2 normal operating condition

3 specific operating condition

4 highest head operating condition

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

NOTE 2 The 100 % speed curve is determined from the operating point requiring the highest head; point 4 in the illustration.

NOTE 3 The compressor rated point (point 1) is the intersection on the 100 % speed line corresponding to the highest flow of any operating point (point 3 in the illustration). Point 1 is not a purchaser-specified point.

NOTE 4 The head-capacity curve at 100 % speed typically extends to at least 115 % of the capacity of the compressor rated point.

NOTE 5 Refer to the applicable standard for the compressor driver such as API 612 or API 616 for trip speed and minimum operating speed limits.

NOTE 6 Refer to 6.8.2.9 for allowable margins of critical speeds to operating speeds.

Figure 1—Centrifugal Compressor Performance Map—Illustration of Terms

3.2 Acronyms, Abbreviations, and Symbols

For the purposes of this document, the following acronyms, abbreviations, and symbols apply.

A_{c1} amplitude at N_{c1}, µm (mil)

AF amplification factor (refer to API 684, Third Edition, and Figure 3)

AF_1 amplification factor of the first critical speed defined as:

$$AF_1 = N_{c1} / (N_2 - N_1)$$

A_{max} maximum probe response amplitude (p-p) considering all vibration probes, over the range of N_{ma} to N_{mc}, for the unbalance amount/case being considered, µm (mil)

AFD adjustable frequency drive

AMB active magnetic bearing

A_{vl} mechanical test vibration limit defined in 6.8.2.10, µm (mil)

CCW counterclockwise (rotation)

CFD computational fluid dynamics

CW clockwise (rotation)

DN nominal diameter

FCSR first undamped critical speed on rigid supports, rpm

FLFPS full-load/full-pressure/full-speed

MAWP maximum allowable working pressure

N operating speed, rpm

N_{c1} rotor first critical speed, rpm

N_{cn} rotor n^{th} critical speed, rpm

N_{ma} minimum allowable speed, rpm

N_{mc} maximum continuous speed, rpm

N_1 initial (lesser) speed at 0.707 × peak amplitude, rpm

N_2 final (greater) speed at 0.707 × peak amplitude, rpm

OEM original equipment manufacturer

PMI positive material identification

PTFE polytetrafluoroethylene

Q_A	anticipated cross coupling for the rotor, kN/mm (klbf/in.); defined as:
	$Q_A = \sum_{i=1}^{S} q_{Ai}$
Q_0	minimum cross coupling needed to achieve a log decrement equal to zero for either minimum or maximum component clearance, kN/mm (klbf/in.)
q_a	cross coupling defined in Equation (10) or Equation (11) for each stage or impeller, kN/mm (klbf/in.)
R_{out}	combined mechanical and electrical runout, μm (mil)
S	number of stages or impellers
S_{a1}	actual separation for first critical speed, rpm
S_{an}	actual separation for n^{th} critical speed, rpm
SI	International System of Units
SM	separation margin (see Figure 3)
SM_1	separation margin for the first critical speed, %
	$= 100 \times S_{a1} / N_{ma}$
SM_a	forced response analysis actual separation margin, %
SM_{an}	separation margin for n^{th} critical speed, %
SM_r	the forced response analysis required separation margin, %
U_a	input unbalance for the rotordynamic response analysis, g-mm (oz-in.)
	$= 2 \times U_r$
U_r	maximum allowable residual unbalance, g-mm (oz-in.)
USC	United States customary
VDDR	vendor drawing and data requirements
VIGV	variable inlet guide vane
δ	logarithmic decrement
δ_A	minimum log decrement at the anticipated cross coupling for either minimum or maximum component clearance
δ_b	basic log decrement of the rotor, oil film seals if used and support system only
δ_f	log decrement of the complete rotor support system

4 Dimensions and Units

4.1 Drawings and maintenance dimensions shall be in the International System of Units (SI) or United States customary (USC) units.

4.2 Use of an SI datasheet indicates that SI units shall be used.

4.3 Use of an USC datasheet indicates that USC units shall be used.

5 Requirements

5.1 Statutory Requirements

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

5.2 Unit Responsibility

The vendor shall assume unit responsibility and shall ensure that all subvendors comply with the requirements of this standard and all reference documents for all equipment and all auxiliary systems included in the scope of the order.

6 Basic Design

6.1 General

6.1.1 [●] Only equipment that is field proven is acceptable. The purchaser shall specify the TRL level from API 691 for qualified equipment.

NOTE Purchasers can use their engineering judgment in determining what equipment is field proven.

6.1.1.1 [●] If specified, the vendor shall provide the documentation to demonstrate that all equipment proposed qualifies as field proven.

6.1.1.2 In the event no such equipment is available, the vendor shall submit an explanation of how their proposed equipment can be considered field proven.

NOTE A possible explanation can be that all components comprising the assembled machine satisfy the field proven definition.

6.1.2 Performance

6.1.2.1 The equipment shall be capable of operating within the entire performance map at all specified operating conditions including transient conditions (e.g. momentary surge, settle-out, trip, and start-up).

6.1.2.2 [●] The purchaser shall specify all operating conditions for the equipment.

NOTE Special operating conditions such as start-up conditions, air dry-out, field commissioning test run, catalyst regeneration, etc. are specified in order to ensure that operation at off-design points can satisfactorily be met.

6.1.2.3 [●] Normal operating point and certified point shall be indicated.

6.1.2.4 The compressor shall be designed to deliver normal head at the normal inlet volumetric flow.

NOTE 1 The purchaser can furnish mass flow that will then be converted to volumetric flow by the vendor.

NOTE 2 See 8.3 of the applicable part for performance tolerances.

6.1.2.5 The section capacity limit shall be at least 115 % of the rated condition.

6.1.2.6 [●] The purchaser shall supply a gas analysis.

6.1.2.7 Gas properties used shall be agreed.

6.1.3 Unit Operation

6.1.3.1 [●] The purchaser shall specify the period of uninterrupted continuous operation.

6.1.3.2 Shutting down the equipment to perform vendor required maintenance or inspection during the specified uninterrupted operation period is not acceptable.

6.1.3.3 The vendor shall advise in the proposal any component designed for finite life or that would result in the need to shut down the equipment within the uninterrupted operational period.

6.1.3.4 Cooling water systems including those on process heat exchangers shall be in accordance with API 614.

6.1.3.5 [●] The purchaser shall specify any requirements for liquid injection.

6.1.3.6 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor at or before the coordination meeting.

6.1.3.7 [●] The applicable electrical codes and hazardous area classification shall be specified.

6.1.3.8 Local electrical codes that apply shall be provided by the purchaser.

6.1.3.9 Motors, generators, instrumentation, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) as specified by the purchaser in 6.1.3.7.

6.1.3.10 Motors, generators, instrumentation, electrical components, and electrical installations shall meet the requirements of IEC 60079-10-1 or NFPA 70, Articles 500 through 505 as applicable, as well as local codes specified and furnished by the purchaser in 6.1.3.8.

6.1.3.11 All components, which are specific as to rotational direction, top or bottom casing half location, or axial location in the machine shall be designed to prevent incorrect installation.

6.1.3.12 [●] The equipment including all auxiliaries shall be suitable for operation under the environmental conditions specified by the purchaser.

NOTE These conditions normally include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, humidity, dusty or corrosive conditions, wind loads, and seismic zone.

6.1.3.13 Control of the sound pressure level of all equipment furnished shall be a joint effort of the purchaser and the vendor having unit responsibility.

6.1.3.13.1 [●] The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified.

6.1.3.13.2 The vendor shall provide expected values for maximum sound pressure level per octave band for the equipment.

6.1.3.13.3 [●] If specified, sound power levels shall be supplied based on calculation methods.

NOTE ASME PTC 36 or ISO 3740, ISO 3744, and ISO 3746 can be consulted for guidance. ISO 10494 can be consulted for gas turbine drive packages.

6.1.3.14 [●] The purchaser shall specify oil for manufacturer's approval.

6.1.3.15 The preferred mineral oil shall correspond to ISO 3448 Grade 32.

NOTE Operating conditions can require higher viscosity oil.

6.1.4 Speed Requirements

6.1.4.1 The equipment's basis for maximum continuous speed (N_{mc}) shall not be less than 105 % of the rated speed for variable-speed machines [including adjustable frequency drives (AFDs)] and shall be equal to the synchronous speed for constant-speed motor drives.

6.1.4.2 The equipment's trip speed shall not be less than the limiting speed of the emergency overspeed device furnished with the driver.

6.1.4.2.1 Table 1 provides typical values for various drivers.

6.1.4.2.2 The purchaser and the vendor shall agree whether turbine overspeed based on loss of inertial load applies to the compressor.

6.1.4.3 Equipment shall be designed to operate simultaneously at the maximum allowable working pressure (MAWP) and trip speed without damage.

6.1.4.4 Equipment driven by induction motors shall be rated based on the actual motor speed for the rated load condition.

Table 1—Driver Trip Speeds

Driver Type	Trip Speed (Times Maximum Continuous Speed)
Steam turbine— Maximum speed rise [a] (% of N_{mc})	
> 7	1.15
≤ 7	1.10
Gas turbine	1.05
Variable-speed motor	1.02
Variable-speed gear	1.02
Constant-speed motor	1.02
Expander/Compressor	1.05
Expander/Generator	1.02
Reciprocating engine	1.10

[a] See API 612 12.2.6 c).

6.1.5 Additional Requirements

6.1.5.1 [●] If specified, the vendor shall review and comment on the purchaser's piping and foundation drawings.

NOTE Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) can adversely affect site performance.

6.1.5.2 [●] If specified, the vendor's representative shall witness:

a) a check of the piping alignment performed by unfastening the main process connections of the equipment;

b) the initial shaft alignment check at ambient conditions (cold alignment);

c) check shaft alignment at the operating temperature (hot alignment).

NOTE Refer to API 686 for basic guidelines for conducting piping alignments, shaft hot and cold alignments.

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

6.1.5.4 [●] If specified, the machine or machines shall be suitable for field run on air.

6.1.5.4.1 Performance parameters, including any required precautions, shall be agreed.

6.2 Materials

6.2.1 General

6.2.1.1 Materials of construction shall be the vendor's standard for the specified operating and site environmental conditions, except as required or prohibited by the datasheets or by this standard.

NOTE Annex F lists material specifications that, when used with appropriate heat treatment or impact testing requirements, or both, are generally considered acceptable for major component parts.

6.2.1.2 The materials of construction of all major components shall be clearly stated in the vendor's proposal.

6.2.1.2.1 Materials shall be identified by reference to applicable international standards, including the material grade.

6.2.1.2.2 When no such designation is available, the vendor's material specification, giving physical properties, chemical composition, and test requirements, shall be included in the proposal.

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

6.2.1.3 [●] The purchaser shall specify any agents (including trace quantities) present in the motive and process fluids and in the site environment, including constituents, that may cause corrosion or erosion.

NOTE 1 Typical agents of concern are hydrogen sulfide, amines, chlorides, cyanide, fluoride, naphthenic acid, mercury, monoethylene glycol, and polythionic acid.

NOTE 2 Selection of materials is a joint effort between the manufacturer and the vendor.

6.2.1.4 The vendor shall specify the tests and inspection procedures that are necessary to ensure that materials are satisfactory for the service.

6.2.1.5 Only fully killed, normalized steels made to fine grain practice are acceptable for pressure-containing machine components. Steel made to a coarse austenitic grain size (e.g. ASTM A515/A515M) shall not be used.

NOTE Low-carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or lower temperatures.

6.2.1.6 If hydrogen sulfide or chlorides have been identified in the gas composition, materials exposed to that gas shall be selected in accordance with the requirements of NACE MR0103/ISO 17945 and where applicable, the referenced NACE SP0472.

NOTE 1 NACE MR0103/ISO 17945 requires restrictive hardness limits, more restrictive weld qualification procedures, and limits to the carbon equivalent levels of materials vs NACE MR0175/ISO 15156 (see 6.2.1.7).

NOTE 2 It is the responsibility of the purchaser to determine the amount of H_2S that can be present, considering normal operation, start-up, shutdown, idle standby, upsets, or unusual operating conditions such as catalyst regeneration.

6.2.1.7 [●] If specified, NACE MR0175/ISO 15156 shall be used in place of NACE MR0103/ISO 17945.

NOTE 1 NACE MR0175/ISO 15156 applies to material potentially subject to sulfide and chloride stress-corrosion cracking in oil and gas production facilities. These are upstream facilities; however, NACE MR0175/ISO 15156 earlier editions have been applied to compressors in downstream facilities since the Fifth Edition of API 617 (1988) prior to the introduction of NACE MR0103.

NOTE 2 A survey conducted of units built in accordance with NACE MR0175/ISO 15156 in previous API 617 editions has indicated no failures. The more restrictive requirements of NACE MR0103/ISO 17945 can therefore not be required to provide sufficient protection against corrosion.

6.2.1.8 For process gas conditions known to cause sulfide stress cracking as identified by NACE MR0103/ISO 17945 or NACE MR0175/ISO 15156, ferrous materials not covered by these standards shall have maximum yield strength of 620 N/mm^2 (90,000 psi) and a maximum Rockwell hardness of HRC 22.

NOTE Shafts in compressors of between-bearing design can exceed the stated limits of yield strength and hardness.

6.2.1.9 For wet H_2S services, components fabricated by welding shall meet the hardness requirements in both the weld and heat-affected zones per NACE SP0472.

6.2.1.10 Austenitic stainless steel parts that are fabricated, hard faced, overlaid, or repaired by welding shall be made of low-carbon or stabilized grades if exposed to conditions that can promote intergranular corrosion.

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

6.2.1.11 In services where stress-corrosion cracking is a possibility, austenitic stainless steels shall be used only as allowed by NACE MR0103/ISO 17945 or NACE MR0175/ISO 15156.

6.2.1.12 Materials that have a yield strength in excess of 827 MPa (120,000 psi) or hardness in excess of Rockwell C 34 are prohibited for use in hydrogen gas service where the partial pressure of hydrogen exceeds 689 kPa (100 psi gauge) or the hydrogen concentration exceeds 90 molar percent at any pressure.

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

6.2.1.14 Minor parts such as nuts, springs, washers, gaskets, and keys shall have corrosion resistance suitable for its environment.

6.2.1.15 Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an anti-seizure compound suitable for the process temperature and compatible with the specified process fluid(s).

NOTE Anti-seizure compounds can alter friction factors and are considered in specifying the torque value in order to achieve the necessary preload.

6.2.1.16 O-ring and gasket materials shall be compatible with all specified conditions.

6.2.1.16.1 O-rings shall not be damaged during gas decompression rates less than that stated in 6.2.1.16.2.

6.2.1.16.2 The maximum gas decompression rate for the equipment shall be stated by the vendor.

NOTE Susceptibility to rapid gas decompression depends on the gas to which the O-ring is exposed, the compounding of the elastomer, temperature of exposure, the rate of decompression, and the number of cycles.

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

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

6.2.2 Coatings

6.2.2.1 [●] If specified, acceptable coatings shall be applied to the rotating and/or stationary components in the gas path.

6.2.2.2 If coatings are applied to rotating components, the final balance check shall be after coatings have been applied.

6.2.2.3 The sequence of procedures for balancing and coating of rotating components shall be agreed.

NOTE 1 It is advisable to prebalance in order to minimize balance corrections and subsequent repair to coating areas for the final acceptance balance. By minimizing the area repaired, a final check balance after repair could possibly not be required.

NOTE 2 API 687 has an informative tutorial appendix on coatings.

6.2.3 Positive Material Identification

6.2.3.1 [●] The purchaser shall specify the extent of positive material identification (PMI) testing for materials, welds, fabrications, and piping, including any sampling requirements.

6.2.3.2 If PMI is specified, techniques providing quantitative results shall be used.

6.2.3.3 PMI testing shall not be considered a substitute for mill test reports, material composite certificates, visual stamps, or markings.

6.2.3.4 PMI results shall be within governing standard limits with allowance for the accuracy of the PMI device as specified by the device manufacturer.

6.2.3.5 If PMI testing has been specified for a fabrication, the components comprising the fabrication, including welds, shall be checked after the fabrication is complete except as permitted in 6.2.3.5.2.

6.2.3.5.1 Testing may be performed prior to any heat treatment.

6.2.3.5.2 Unique (non-stock) components such as impellers, blading, and shafts may be tested after manufacturing and prior to rotor assembly.

6.2.3.5.3 The purchaser and the vendor shall agree upon what criteria to use for PMI testing.

6.2.4 Low Temperature Service

NOTE See definition 3.1.21.

6.2.4.1 Pressure casings and rotating elements shall be designed for the prevention of brittle fracture.

6.2.4.2 [●] The purchaser shall specify the minimum temperature and concurrent pressure including any transient operation.

6.2.4.3 Vendor shall establish the minimum design metal temperature, impact test, and other material requirements based on the information supplied by the purchaser.

NOTE Normally, this will be the lower of the minimum surrounding ambient temperature or minimum fluid pumping temperature; however, the purchaser can specify a minimum temperature based on operating properties of the pumped fluid, such as auto refrigeration at reduced pressures.

6.2.4.4 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 A good design practice will include the selection of fabrication methods, welding procedures, and materials for vendor-furnished steel pressure retaining parts that could be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for materials in internationally recognized standards such as the ASME *BPVC* and ANSI standards are based on minimum tensile properties.

6.2.4.5 All carbon and low-alloy steel pressure-containing components for low temperature service including nozzles, flanges, and weldments shall be impact tested in accordance with the requirements of Section VIII, Division 1, Sections UCS-65 through 68 of the ASME *BPVC*, appropriate European standards, or other purchaser-approved code.

6.2.4.6 High-alloy steels shall be tested in accordance with Section VIII, Division I, Section UHA-51 of the ASME *BPVC*, European standards, or other purchaser-approved code.

NOTE In some situations, impact testing of a material will not be required depending on the minimum design metal temperature, thermal, mechanical and cyclic loading, and the governing thickness. Refer to requirements of Section VIII, Division I, Section UG-20F of the ASME *BPVC*, for example.

6.2.4.7 Governing thickness used to determine impact testing requirements shall be the greater of the following:

a) the nominal thickness of the largest butt-welded joint;

b) the largest nominal section for pressure containment, excluding:

   1) structural support sections such as feet or lugs,

   2) sections with increased thickness required for rigidity to mitigate shaft deflection, and

   3) structural sections required for attachment or inclusion of mechanical features such as jackets or seal chambers;

c) one fourth of the nominal flange thickness, including parting flange thickness for axially split casings (in recognition that the predominant flange stress is not a membrane stress).

6.2.4.8 The results of the impact testing shall meet the minimum impact energy requirements of Section VIII, Division I, Section UG-84 of the ASME *BPVC*, appropriate European standards, or other purchaser-approved code.

6.2.4.9 [●] For materials and thicknesses not covered by Section VIII, Division I of the ASME *BPVC*, European standards, or other purchaser-approved code, the purchaser shall specify requirements.

6.2.5 Castings

6.2.5.1 Castings shall comply with material specification requirements regarding porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar defects.

6.2.5.2 Surfaces of castings shall be cleaned by sandblasting, shot blasting, chemical cleaning, or other standard methods.

6.2.5.3 Mold-parting fins and the remains of gates and risers shall be chipped, filed, or ground flush.

6.2.5.4 Where chaplets are necessary, they shall be clean and corrosion free (plating is permitted) and of a composition compatible with the casting.

6.2.5.5 Pressure-containing ferrous castings shall only be repaired as specified in 6.2.5.5.1 through 6.2.5.5.6.

6.2.5.5.1 Weldable grades of steel castings shall be repaired, using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as Section VIII, Division 1 and Section IX of the ASME *BPVC* or appropriate European standards.

6.2.5.5.2 After major weld repairs and before hydro test, the complete repaired casting shall be given a post-weld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining operations.

6.2.5.5.3 Post-weld heat treatment on individual minor weld repairs after final machining may be performed by local heat treatments.

6.2.5.5.4 Ductile iron may be repaired by plugging within the limits specified in ASTM A395/A395M. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

6.2.5.5.5 All repairs that are not covered by ASTM or appropriate European specifications shall be subject to the purchaser's approval.

6.2.5.5.6 If either NACE MR0103/ISO 17945 (per 6.2.1.6) or NACE MR0175/ISO 15156 (per 6.2.1.7) has been specified, the completed weld repairs shall meet the requirements of the applicable standard.

6.2.5.6 Cored voids, which become fully enclosed by methods such as plugging, welding, or assembly, are prohibited.

6.2.5.7 All ductile (nodular) iron castings shall be produced in accordance with ASTM A395/A395M or other internationally recognized standard as approved.

6.2.5.8 Brinell hardness tests shall be made on the actual casting at feasible critical sections such as section changes, flanges, and other accessible locations.

6.2.5.8.1 Sufficient surface material shall be removed before hardness tests are made to eliminate any skin effect.

6.2.5.8.2 Tests shall also be made at the extremities of the casting at locations that represent the sections poured first and last.

6.2.5.8.3 These shall be made in addition to hardness test on keel or Y blocks in accordance with 6.2.5.9.1.

6.2.5.9 The production of the ductile (nodular) iron castings shall conform to the conditions specified in 6.2.5.9.1 through 6.2.5.9.4.

6.2.5.9.1 The keel or Y block cast at the end of the pour shall have a thickness not less than the thickness of critical sections of the main casting.

NOTE Critical sections are typically heavy section changes, high-stress points such as flanges. Normally, bosses and similar sections are not considered critical sections of a casting. If critical sections of a casting have different thicknesses, average size keel or Y blocks can be selected in accordance with ASTM A395/A395M.

6.2.5.9.1.1 This test block shall be tested for tensile strength and hardness and shall be microscopically examined.

6.2.5.9.1.2 Classification of graphite nodules under microscopic examination shall be in accordance with ASTM A247.

6.2.5.9.1.3 There shall be no intercellular flake graphite.

6.2.5.9.2 A minimum of one set (three samples) of Charpy V-notch impact specimens at one-third the thickness of the test block shall be made from the material adjacent to the tensile specimen on each keel or Y block.

6.2.5.9.2.1 All three specimens shall have an impact value not less than 12 J (9 ft-lbf).

6.2.5.9.2.2 The mean of the three specimens shall not be less than 14 J (10 ft-lbf) at room temperature.

6.2.5.9.3 If purchaser approved, nonpressurized ductile (nodular) iron castings may be produced in accordance with ASTM A536 or other equivalent internationally recognized standard.

6.2.5.9.4 An “as-cast” sample from each ladle shall be chemically analyzed.

6.2.6 Forgings

6.2.6.1 The forging material should be selected from those listed in Annex F as applicable.

6.2.6.2 Pressure-containing ferrous forgings shall not be repaired except as specified in 6.2.6.2.1 through 6.2.6.2.4.

6.2.6.2.1 Weldable grades of steel forgings shall be repaired by welding using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as Section VIII, Division I and Section IX of the ASME *BPVC* or other purchaser-approved code.

6.2.6.2.2 After major weld repairs, and before hydro test, the complete forging shall be given a post-weld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal.

6.2.6.2.3 Post-weld heat treatment on individual minor weld repairs after final machining may be performed by local heat treatments.

6.2.6.2.4 All repairs that are not covered by ASTM or appropriate European specifications shall be subject to the purchaser’s approval.

6.2.7 Welding

6.2.7.1 Nonpressurized component welding, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed and inspected by personnel and procedures qualified in accordance with AWS D1.1/D1.1M or ASME *BPVC* Section IX or ISO 9606 Parts 1–6 or other purchaser-approved standard.

6.2.7.2 Welding of piping, pressure-containing parts and rotating parts, weld repairs, and any dissimilar-metal welds shall be performed and inspected by personnel and procedures qualified in accordance with Section VIII, Division I and Section IX of the ASME *BPVC* or purchaser-approved standard, such as ISO 9606 and ISO 15607 and ISO 15614-1 for welder qualifications, or procedures.

6.3 Casings

6.3.1 Pressure-containing Casings

6.3.1.1 The pressure casing may be designed with the aid of numerical methods and shall be designed in accordance with 6.3.1.1.1 through 6.3.1.1.4.

6.3.1.1.1 The allowable tensile stress used in the design of the pressure casing for any material shall be less than 0.25 times the minimum ultimate tensile strength and less than 0.67 times the minimum yield strength at the maximum allowable temperature for that material.

NOTE This is intended to apply to the average hoop stress of the casing.

6.3.1.1.2 For cast materials, the allowable tensile stress shall be multiplied by the appropriate casting factor as shown in Table 2.

Table 2—Casting Factors

Type of Nondestructive Examination	Casting Factor
Visual, magnetic particle and/or liquid penetrant	0.8
Spot radiography	0.9
Ultrasonic	0.9
Full radiography	1.0

NOTE In general, deflection is the determining consideration in the design of casings. Ultimate tensile or yield strength is seldom the limiting factor.

6.3.1.1.3 A corrosion allowance of at least 3 mm (0.125 in.) shall be added to the casing thickness used in 6.3.1.1.1. This corrosion allowance applies to all auxiliary connections exposed to the same fluid as the pressure-containing casing.

6.3.1.1.4 The vendor may propose alternative corrosion allowances for consideration if materials of construction with superior corrosion resistance are employed without affecting functionality, safety, and reliability.

6.3.1.2 The casing joint bolting shall be in accordance with 6.3.1.2.1 through 6.3.1.2.4.

6.3.1.2.1 For casing joint bolting, the allowable tensile stress (as determined in 6.3.1.1.1) shall be used to determine the total bolting area based on hydrostatic load and gasket preload as applicable.

6.3.1.2.2 The preload stress shall not exceed 75 % of the bolting material minimum yield strength.

6.3.1.2.3 During hydro test, the bolting stress shall not exceed 90 % of the bolting material minimum yield strength.

6.3.1.2.4 Torque values shall not be used to determine bolt elongation.

NOTE Thread stress in the nut or case can be the limiting factor in the strength of the bolting.

6.3.1.3 For flammable or toxic gases, casings shall be steel or purchaser-approved alloy.

6.3.1.4 For air or nonflammable gases, casings may be steel, ductile iron, or cast iron materials depending on the following ratings.

a) Ductile iron casings can be used up to the flange rating in accordance with ASME B16.42, Class 300.

b) Cast iron casings can be used up to the flange rating in accordance with ASME B16.1, Class 250.

6.3.1.5 Jackscrews, guide rods, cylindrical casing-alignment dowels, and/or special tools shall be provided to facilitate disassembly and reassembly.

NOTE "Special tools" could be extraction rigs for radially split equipment, or rollers on the bundles of these machines.

6.3.1.5.1 Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly.

6.3.1.5.2 Lifting lugs or eyebolts/safety hoist rings shall be provided for lifting only the top half of the casing of axially split casings.

6.3.1.5.3 If jackscrews are used as a means of parting contacting faces, the load bearing face shall be relieved (counter bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face.

6.3.1.6 The use of threaded holes in pressure parts of cast iron casings is allowed and shall be per the following.

6.3.1.6.1 To prevent leakage in pressure sections of casings, metal equal in thickness to at least 12 mm ($^1/_2$ in.), in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes.

6.3.1.6.2 The depth of the threaded holes shall be at least 1.5 times the diameter of the threaded insert (stud, plug, etc.).

6.3.1.7 The sealing of stud clearance holes to prevent leakage is not permitted.

6.3.1.8 Bolting shall be furnished as specified in 6.3.1.8.1 through 6.3.1.8.9.

6.3.1.8.1 The details of threading shall conform to ASME B1.1, ASME B1.13M, or ISO 261.

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

NOTE 2 Glossary of terms for screw threads can be found in ASME B18.12.

6.3.1.8.2 Studs shall be supplied on the main joint of axially split casings and bolted end covers of radially split casings.

6.3.1.8.3 Studs shall be used instead of cap screws, on all other external joints, except where hexagonal head cap screws are essential for assembly purposes and have been approved by the purchaser.

6.3.1.8.4 Clearance shall be provided at bolting locations to permit use of tools to install and remove bolting.

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

6.3.1.8.6 Vendor shall advise whether bolting that needs to be disassembled for maintenance is metric or USC thread series.

6.3.1.8.7 The minimum quality bolting material for pressure joints shall be carbon steel (such as ASTM A307, Grade B) for cast iron casings and high-temperature alloy steel (such as ASTM A193, Grade B7) for steel casings.

6.3.1.8.7.1 Carbon steel nuts (such as ASTM A194, Grade 2H) shall be used.

6.3.1.8.7.2 Where space is limited, case-hardened carbon steel nuts (such as ASTM A563, Grade A) shall be used.

NOTE For low temperature requirements, see 6.2.4.

6.3.1.8.8 Fasteners (excluding washers and headless set-screws) shall have the material grade and manufacturer's identification symbols applied to one end of studs $^3/_8$ in. (10 mm) in diameter and larger and to the heads of bolts $^1/_4$ in. (6 mm) in diameter and larger. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.

6.3.1.8.9 Studs shall be marked on the exposed end.

6.3.1.9 Materials, casting factors, and the quality of any welding shall be equal to those required by Section VIII, Division 1 of the ASME *BPVC* or other purchaser-approved standard.

6.3.1.10 The manufacturer's data report forms, as specified in the ASME *BPVC*, are not required unless required by regulation.

6.3.1.11 To prevent the buildup of potential voltages, residual magnetism of the free air gauss level in the casings and all stationary components, except bearing and seal assemblies, shall not exceed ±4 gauss when measured with a calibrated Hall effect probe on the surface of the part.

6.3.2 Casing Repairs and Inspections

6.3.2.1 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 the applicable qualified procedures (see 6.3.1.9).

6.3.2.2 Weld repairs shall be nondestructively tested by the same method used to detect the original flaw.

6.3.2.3 The minimum level of inspection after the repair shall be by the magnetic particle method in accordance with 8.2.5 for magnetic material and by the liquid penetrant method in accordance with 8.2.6 for nonmagnetic material.

6.3.2.4 The purchaser shall be notified before making a major repair to a pressure-containing part.

6.3.2.4.1 Major repair, for the purpose of purchaser notification only, is any defect that equals or exceeds any of the three criteria defined below:

a) the depth of the cavity prepared for repair welding exceeds 50 % of the component wall thickness;

b) the length of the cavity prepared for repair welding is longer than 150 mm (6 in.) in any direction;

c) the total area of all repairs to the part under repair exceeds 10 % of the surface area of the part.

6.3.2.4.2 Procedures for major repairs shall be subject to review by the purchaser prior to any repair.

6.3.2.5 Actual repairs to pressure-containing parts shall be made as required by the following documents.

a) The repair of plates, prior to fabrication, shall be performed in accordance with the material standard to which the plate was purchased.

b) The repair of castings or forgings shall be performed prior to final machining in accordance with the material standard to which the casting or forging was purchased.

c) The repair of a fabricated casing or the defect in either a weld or the base metal of a cast or fabricated casing, uncovered during preliminary or final machining, shall be performed in accordance with Section VIII of the ASME *BPVC* or other purchaser-approved standard. A weld map of all repaired areas shall be provided by the vendor.

d) If NACE MR0103/ISO 17945 (per 6.2.1.6) or NACE MR0175/ISO 15156 (per 6.2.1.7) is applicable, the material and welding requirements of the specified NACE document shall apply to the repairs.

6.3.2.6 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 6.3.2.6.1 through 6.3.2.6.7.

6.3.2.6.1 Before welding, plate edges shall be examined by the magnetic particle method to confirm the absence of laminations.

6.3.2.6.2 Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after post-weld heat treatment.

6.3.2.6.3 [●] If specified, the quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.

6.3.2.6.4 Pressure-containing welds, including welds of the case to axial or radial joint flanges, shall be full penetration (complete joint) welds.

NOTE For auxiliary connections, refer to 6.4.3.

6.3.2.6.5 Casings and fabrications shall be stress relieved by heat treating regardless of thickness.

6.3.2.6.6 All pressure-containing welds shall be examined as required by Section VIII, Division 1 of the ASME *BPVC*.

6.3.2.6.7 Requirements for additional examination shall be agreed.

NOTE See 6.3.3 for required procedures and acceptance criteria.

6.3.3 Material Inspection of Pressure-containing Parts

NOTE Refer to 8.2.2 for inspection of non-pressure-containing parts.

6.3.3.1 Regardless of the generalized limits presented in this section, it shall be the vendor's responsibility to review the design limits of all materials and welds in the event that more stringent requirements are specified.

6.3.3.2 Defects that exceed the limits imposed in 6.3.3.3 and 6.3.3.4 shall be removed to meet the quality standards cited, as determined by additional magnetic particle or liquid penetrant inspection as applicable prior to repair welding.

6.3.3.3 [●] If radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the procedures and acceptance criteria in Table 3 shall apply, except as noted in 8.2.2.

Table 3—ASME Materials Inspection Standards

Type of Inspection	Methods	Acceptance Criteria	
		For Fabrications	For Castings
Radiography	Section V, Articles 2 and 22 of the ASME *BPVC*	Section VIII, Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography) of the ASME *BPVC*	Section VIII, Division 1, Appendix 7 of the ASME *BPVC*
Ultrasonic inspection	Section V, Articles 4, 5, and 23 of the ASME *BPVC*	Section VIII, Division 1, UW-53 and Appendix 12 of the ASME *BPVC*	Section VIII, Division 1, Appendix 7 of the ASME *BPVC*
Magnetic particle inspection	Section V, Articles 7 and 25 of the ASME *BPVC*	Section VIII, Division 1, Appendix 6 of the ASME *BPVC*	See acceptance criteria in 6.3.3.4 and Table 4
Liquid penetrant inspection	Section V, Articles 6 and 24 of the ASME *BPVC*	Section VIII, Division 1, Appendix 8 of the ASME *BPVC*	Section VIII, Division 1, Appendix 7 of the ASME *BPVC*

6.3.3.3.1 Spot radiography shall consist of a minimum of one 150 mm (6 in.) spot radiograph for each 7.5 m (25 ft) of weld on each casing. As a minimum, one spot radiograph is required for each welding procedure and welder used for pressure-containing welds.

6.3.3.3.2 For magnetic particle inspections, linear indications shall be considered relevant only if the major dimension exceeds 1.5 mm ($^{1}/_{16}$ in.).

6.3.3.3.3 Individual indications that are separated by less than 1.5 mm ($^{1}/_{16}$ in.) shall be considered continuous.

6.3.3.4 Cast steel casing parts shall be examined by magnetic particle methods.

6.3.3.4.1 Acceptability of defects shall be based on a comparison with the photographs in ASTM E125.

6.3.3.4.2 For each type of defect, the degree of severity shall not exceed the limits specified in Table 4.

Table 4—Maximum Severity of Defects in Castings

Type	Defect	Degree
I	Linear discontinuities	1
II	Shrinkage	2
III	Inclusions	2
IV	Chills and chaplets	1
V	Porosity	1
VI	Welds	1

6.4 Pressure Connections

6.4.1 General

6.4.1.1 All connections shall be flanged or machined and studded, except where threaded connections are permitted by 6.3.1.6 or 6.4.3.

6.4.1.2 All process gas connections to the casing shall be suitable for the MAWP.

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

6.4.1.4 All openings or nozzles for piping connections on pressure casings shall be in accordance with ASME B1.20.1 (ISO 6708) and at least NPS $^{1}/_{2}$ (DN 15) for equipment with a main process connection NPS 2 (DN 50) and smaller, or NPS $^{3}/_{4}$ (DN 20) for equipment with all main process connections larger than NPS 2 (DN 50).

6.4.1.5 Sizes NPS 1 $^{1}/_{4}$, 2 $^{1}/_{2}$, 3 $^{1}/_{2}$, 5, 7, and 9 (DN 32, DN 65, DN 90, DN 125, DN 175, and DN 225) shall not be used.

NOTE NPS designates pipe per ASME B1.20.1.

6.4.1.6 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping.

6.4.1.7 All welding of connections shall be completed before the casing is hydrostatically tested (see 8.3.2).

6.4.1.8 Casing drain connections shall be per 6.4.1.8.1 through 6.4.1.8.5.

6.4.1.8.1 For axially split pressure casings, the vendor shall provide connections for complete drainage of all gas passages.

6.4.1.8.2 For radially split pressure casings, the drains shall be located at the lowest point of each inlet section, the lowest point of the section between the inner and outer casings, and the lowest point of each discharge section.

6.4.1.8.3 Number and size of drain connections shall be provided.

6.4.1.8.4 [●] If specified, individual stage drains for radially split pressure casings, including a drain for the balance piston cavity, shall be provided.

NOTE If the vendor can show that their standard design provides complete drainage of all gas passages, individual stage drains would not be required.

6.4.1.8.5 [●] If specified, if casing drains are provided, the individual drains shall be manifolded into a common drain connection.

6.4.2 Main Process Connections

6.4.2.1 [●] Main process connections shall be flanged or machined and studded. Orientation shall be as specified.

NOTE Main process connections include all process inlets and outlets including those for side loads and intermediate cooling.

6.4.2.2 The CLASS system applies, and all flanges shall conform to ASME B16.1, B16.5, B16.42, or B16.47 Series B, as applicable.

6.4.2.3 [●] If the PN system is specified, all flanges shall conform to EN 1092-1 or EN 1092-2 as applicable, except as specified in 6.4.2.4 through 6.4.2.18.

NOTE EN 1092 flanges are PN 6, 10, 16, 25, 40, 63, 100, 160, 250, 320, and 400.

6.4.2.4 Steel flanges shall conform to the dimensional requirements of ASME B16.5 or B16.47 Series B or EN 1092-1, as applicable.

6.4.2.5 [●] If specified, ASME B16.47 Series A steel flanges shall be provided.

NOTE ASME B16.47 covers flange diameters from NPS 26 through NPS 60.

6.4.2.6 Machined and studded connections and flanges not in accordance with ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47 or EN 1092-1, EN 1092-2 require purchaser's approval.

6.4.2.7 The vendor shall supply mating flanges, studs, and nuts for the nonstandard connections in 6.4.2.6.

6.4.2.8 The vendor shall state the particular flange standard and provide details of the flanges that are being provided.

6.4.2.9 Cast, ductile, and malleable iron flanges shall be flat faced and conform to the dimensional requirements of ASME B16.1 or ASME 16.42 or EN 1092-2, as applicable.

a) Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes NPS 8 and smaller.

b) PN 20 (Class 125) flanges shall have a minimum thickness equal to PN 50 (Class 250) for sizes DN 200 (NPS 8) and smaller.

c) PN16 flanges shall have a minimum thickness equal to PN25 for sizes DN 200 and smaller.

6.4.2.10 Flat face flanges with full raised face thickness are acceptable on casings of all materials.

6.4.2.11 Flanges in all materials that are thicker or have a larger outside diameter than required by ASME (EN) are acceptable.

6.4.2.11.1 Nonstandard (oversized) flanges shall be completely dimensioned on the arrangement drawing.

6.4.2.11.2 If oversized flanges require studs or bolts of nonstandard length, this requirement shall be identified on the arrangement drawing.

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

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

6.4.2.14 For steel flanges imperfections in the flange gasket surface shall not exceed that permitted in ASME B16.5 or ASME B16.47, as applicable.

6.4.2.15 [●] Machined and studded connections shall conform to the facing and drilling requirements of ASME B16.1, ASME B16.5, ASME B16.42, or ASME B16.47 or EN 1092-1, EN 1092-2, as specified.

6.4.2.16 Studs and nuts shall be provided installed, and the first 1.5 threads at both ends of each stud shall be removed.

NOTE Threads are removed at the end of the stud to allow the stud to bottom without damaging the end threads in the hole. Threads are removed from both ends of the stud to allow either end of the stud to be inserted into the threaded hole.

6.4.2.17 To minimize nozzle loading, and facilitate installation of piping, machine flanges shall be parallel to the plane of the flange as shown on the general arrangement drawing to within 0.5°.

6.4.2.18 Studs or bolt holes shall straddle centerlines parallel to the main axes of the flange.

6.4.3 Auxiliary Connections

6.4.3.1 Auxiliary connections may include but are not limited to those for vents, liquid injection, drains (see 6.4.1.8), water cooling, lube and seal oil, flushing, seal and buffer gas, and balance piston cavity.

6.4.3.2 Auxiliary connections shall conform to ASME B16.1, ASME B16.5, or ASME B16.42 (EN 1092-1), or SAE J518, as applicable.

6.4.3.3 Auxiliary connections other than lube oil, seal oil, or dry gas seal connections shall be socket-welded and flanged or machined and studded.

6.4.3.4 Auxiliary connections for lube oil, seal oil, or dry gas seal operation shall use weld-neck flanges or be machined and studded.

6.4.3.5 Socket-welds shall not be used for auxiliary connections for lube oil, seal oil, or dry gas seal operation.

6.4.3.6 Pipe nipples screwed or welded to the casing, preferably not more than 150 mm (6 in.) long, shall be a minimum of Schedule 160 seamless for sizes DN 40 (NPS 1 $^1/_2$) and smaller and a minimum of Schedule 80 for DN 50 (NPS 2).

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

6.4.4 Requirements for Threaded Connections

6.4.4.1 [●] Threaded openings for tapered pipe threads shall conform to ASME B1.20.1 or ISO 7-1 or DIN ISO 228-1, as specified.

6.4.4.1.1 If ISO 7-1 has been specified, tapered or straight internal threads shall also be specified.

6.4.4.1.2 Bosses for pipe threads shall conform to ASME B16.5.

6.4.4.1.3 Threaded connections shall be brought to a remote flange that can be disassembled for maintenance so as to require the least amount of assembly/disassembly of the threaded connection.

NOTE ISO 7-1 and ASME B1.20.1 are not equivalent for tapered threads; however, they are sufficiently close that stripped threads and/or sealing problems can result in installing incorrect parts (including later in the field). Caution is therefore taken in specifying a standard that agrees with the standard used within the plant.

6.4.4.2 [●] Pipe threads shall be taper thread conforming to ASME B1.20.1 or ISO 7-1, as specified.

6.4.4.3 Threaded connections shall not be seal welded.

6.4.4.4 For threaded connections that are connected to pipe, a pipe nipple, preferably not more than 150 mm (6 in.) long, schedule 160 seamless minimum shall be installed in the threaded opening.

6.4.4.4.1 Each pipe nipple shall be terminated with a welding-neck or socket-weld flange.

6.4.4.4.2 The nipple and flange materials shall meet the requirements of 6.4.1.5.

6.4.4.5 Threaded openings not required to be connected to piping shall be plugged with solid, round-head steel plugs in accordance with ASME B16.11.

6.4.4.5.1 As a minimum, these plugs shall meet the material requirements of the pressure casing.

6.4.4.5.2 Plugs that may later require removal shall be of a corrosion-resistant material.

6.4.4.5.3 Plastic plugs are not permitted.

6.4.4.6 A process-compatible thread sealant/lubricant rated for the maximum allowable temperature shall be used on all threaded connections.

6.4.4.7 Thread tape shall not be used.

6.5 Stationary Components

6.5.1 Casing Support Structures

Machines requiring alignment shall meet the following criteria.

a) Mounting surfaces shall be machined to a finish of 6 μm (250 μin.) arithmetic average roughness (Ra) or better.

b) Each mounting surface shall be machined within a flatness of 40 μm per linear meter (500 μin. per linear ft) of mounting surface.

c) Different mounting planes shall be parallel to each other within 50 μm (0.002 in.) over the distance between mounting surfaces.

d) The upper machined or spot-faced surface shall be directionally parallel to the mounting surface.

e) Hold-down bolt holes shall be drilled directionally perpendicular to the mounting surfaces.

f) The mounting hole in the equipment feet shall be at least 12 mm ($^1/_2$ in.) larger in diameter than the hold-down bolt.

g) Mounting holes in equipment feet shall be machined or spot faced to a diameter suitable for a washer positioned eccentrically around the bolt to allow for equipment alignment. Holes shall not be slotted.

h) The equipment feet shall be provided with vertical jack-screws and shall be drilled with pilot holes that are accessible for use in final doweling.

NOTE 1 Mounting requirements for equipment mounting feet are covered in Parts 2, 3, and 4.

NOTE 2 Expander-compressors as covered in Part 4 do not require alignment since driver and compressor are on the same shaft.

NOTE 3 Refer to 7.2.1.2.1 for horizontal jackscrew requirements.

6.5.2 External Forces and Moments

External forces and moment information can be found in the applicable parts of this standard.

6.5.3 Guide Vanes, Stators, and Stationary Internals

Refer to subsequent parts of this standard for specific requirements.

6.6 Rotating Elements

6.6.1 General

6.6.1.1 Shaft ends for couplings shall conform to the requirements of API 671.

6.6.1.2 All shaft sensing areas (both radial vibration and axial position) shall be free from stencil or scribe marks or any other surface discontinuity for a minimum of one probe tip diameter on each side of the probe.

6.6.1.3 The final surface finish of sensing areas observed by radial and axial proximity probes shall be a maximum of 0.8 μm (32 μin.) rms.

6.6.1.3.1 These areas shall be demagnetized (see API 670) or otherwise treated so that the required combined total electrical and mechanical runout can be met.

6.6.1.3.2 For areas observed by radial vibration probes, the combined total electrical and mechanical runout shall not exceed the value from Equation (1) or 6.35 μm (0.25 mil), whichever is greater.

In SI units:

$$R_{\text{out}} = \frac{25.4}{4}\sqrt{\frac{12{,}000}{N_{\text{mc}}}} \tag{1a}$$

In USC units:

$$R_{\text{out}} = \frac{1}{4}\sqrt{\frac{12{,}000}{N_{\text{mc}}}} \tag{1b}$$

where

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

R_{out} is the allowable runout (μm/mils).

For areas observed by axial proximity probes, the combined total electrical and mechanical runout shall not exceed 0.5 mil (12.7 μm).

NOTE 1 If all reasonable efforts fail to achieve the limits noted in 6.6.1.3.2, the vendor and the purchaser can agree on alternate acceptance criteria.

NOTE 2 Diamond burnishing of probe areas has been shown to be effective in reducing electrical runout.

NOTE 3 The use of magnetic holders or chucks in the probe areas during manufacture or handling will cause electrical runout.

NOTE 4 Shaft materials such as 17-4 PH frequently exhibit excessive electrical runout. Some vendors have successfully reduced electrical runout to acceptable levels with treatments such as the application of 1 mm (0.04 in.) radial thickness of metalized aluminum.

6.6.1.4 To prevent the buildup of potential voltages in the shaft, residual magnetism of the rotating element free air gauss level shall not exceed ±2 gauss when measured with a calibrated Hall effect probe on the surface of the part.

NOTE The free air gauss level is measured while suspending the rotor from nonconductive straps with no influence from stray magnetic fields.

6.6.1.5 Integral thrust collars are preferred.

6.6.1.5.1 Removable thrust collars shall be furnished only if they are required for removal of shaft end seals.

6.6.1.5.2 If removable collars are furnished (for assembly and maintenance purposes), they shall be locked to the shaft to prevent movement axially and tangentially and mounted to the shaft with an interference fit to minimize fretting.

6.6.1.5.3 If integral collars larger than 125 mm (5 in.) diameter are furnished, they shall be provided with at least 3 mm (0.125 in.) of additional thickness to enable refinishing if the collar is damaged.

6.6.1.6 Both faces of thrust collars shall have a surface finish of not more than 0.4 μm (16 μin.) rms, and the axial total indicator runout of either face shall not exceed 12.7 μm (0.5 mils).

6.6.1.7 Stationary labyrinth seals shall have replaceable shaft sleeves or be designed so that major rotating parts need not be replaced.

6.6.1.8 Labyrinth-type seals with the teeth on the rotating element shall have a replaceable nonrotating element of an abradable material.

6.6.1.9 Metal plating or metal spray (HVOF) is not permitted on the coupling fits.

6.6.1.10 Any axial clearance requirement between shaft sleeves to allow for expansion shall be clearly indicated on the rotor drawing.

6.6.2 Impellers

6.6.2.1 Impellers shall be of welded, brazed, milled, electro-eroded, or cast construction.

6.6.2.1.1 Other manufacturing methods may be permitted if approved by the purchaser.

6.6.2.1.2 Each impeller shall be marked with a unique identification number.

6.6.2.2 Impellers may consist of forged and cast components.

6.6.2.2.1 Other component manufacturing methods may be permitted if approved by the purchaser.

6.6.2.2.2 Welds in the gas passageway shall be smooth and free of weld spatter.

6.6.2.2.3 Impellers shall be heat treated and stress relieved after welding.

6.6.2.2.4 Impeller blade entrance and exit tips shall not have knife edges.

6.6.2.3 All accessible weld surfaces on welded impellers and finish machined surfaces of electro-eroded impellers shall be inspected by visual and magnetic particle or liquid penetrant examination.

6.6.2.3.1 Impeller fabrications resulting in joints that are not visually accessible, such as brazed joints, shall be subjected to ultrasonic examination to verify joint integrity.

6.6.2.3.2 Refer to 8.2.2 for material inspection methods and 8.2.2.1.2 for acceptance criteria.

6.6.2.4 Cast impellers hubs and covers shall be inspected by radiographic or ultrasonic means prior to finish machining.

6.6.2.4.1 Details of inspection techniques and acceptance criteria shall be agreed.

6.6.2.4.2 Refer to 8.2.2 for material inspection methods and 8.2.2.1.2 for acceptance criteria.

6.6.2.5 Upgrade or repair welding of impellers after overspeed testing may be permitted only with the purchaser's approval.

6.6.2.6 Welding as a means of balancing an impeller is not permitted.

6.6.2.7 After the overspeed test described in 8.3.3, each impeller shall be fully examined by means of magnetic particle or liquid penetrant methods.

NOTE Refer to 8.2.2 for material inspection methods and 8.2.2.1.2 for acceptance criteria.

6.6.2.8 Plating or coating of the impeller bore is not permitted without purchaser's approval.

6.7 Bearings and Bearing Housings

6.7.1 General

6.7.1.1 Radial and thrust bearings shall be as specified in the subsequent parts of this standard.

6.7.1.2 Hydrodynamic bearings shall be inspected to ensure babbitt to backing material contact of not less than 99 %.

6.7.1.3 The bond contact check shall be performed by ultrasonic testing flaw detection methods in the main part or body of the part.

6.7.1.4 A PT (dye penetrant) inspection shall be required to ensure that no side separation exists.

6.7.1.5 For machines using active magnetic bearings (AMBs), refer to Annex D for requirements.

6.7.2 Hydrodynamic Radial Bearings

Hydrodynamic radial bearings shall be in accordance with the applicable parts of this standard.

6.7.3 Hydrodynamic Thrust Bearings

6.7.3.1 For gear couplings, the external thrust force shall be calculated from Equation (2).

In SI units:

$$F = \frac{(0.25)(9550)P_r}{N_r D} \tag{2a}$$

In USC units:

$$F = \frac{(0.25)(63{,}300)P_r}{N_r D} \tag{2b}$$

where

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

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

N_r is the rated speed, in rpm;

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

6.7.3.2 Thrust forces for flexible-element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

6.7.3.3 If the thrust forces from two or more rotors are carried by one thrust bearing (such as from a gear box or motor), the resultant of the forces shall be used, provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

6.7.3.4 Hydrodynamic thrust bearings shall be selected at no more than 50 % of the bearing manufacturer's ultimate load rating. In sizing thrust bearings, consider the following for each specified application:

a) shaft speed;

b) temperature of the bearing babbitt;

c) deflection of the bearing pad;

d) minimum oil film thickness;

e) feed rate, viscosity, and supply conditions of the oil over the specified allowable oil supply condition range;

f) design configuration of the bearing;

g) babbitt or other bearing surface material alloy and pad material;

h) turbulence of the oil film;

i) load changes due to process changes over the specified operating range.

6.7.3.5 Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions.

6.7.3.6 Calculations of the thrust forces shall include, but shall not be limited to, the following factors:

a) seal nominal design clearances and twice the maximum design clearances;

b) pressurized rotor diameter step changes;

c) stage maximum differential pressures;

d) specified extreme variations in inlet, interstage, and discharge pressures;

e) any anticipated transient loading (i.e. from valve opening or closing);

f) maximum thrust force that may be transmitted to the compressor thrust bearing by other equipment in the train (i.e. couplings, gears, or a motor without a thrust bearing);

g) maximum thrust force from the sleeve bearing type drive if the motor or generator is directly connected.

6.7.4 Bearing Housings

6.7.4.1 Bearing housings shall be equipped with replaceable labyrinth-type end seals and deflectors where the shaft passes through the housing.

6.7.4.1.1 Lip-type seals shall not be used.

6.7.4.1.2 Bearing housing seals and deflectors shall be made of spark-resistant materials.

6.7.4.1.3 Bearing housing shall be designed to retain oil in the housing and prevent entry of foreign material into the housing without the requirement for external service such as an air purge or grease.

6.7.4.2 The drain system shall maintain the oil and foam level below shaft seals.

6.7.4.3 Provisions for the installation of required instrumentation shall be provided.

6.7.4.4 Where practical, oil and instrument connections shall be in the lower half of the bearing housing to eliminate the need for their removal during bearing inspections and sealed to prevent leakage.

6.7.4.5 Instrument connections shall be above the oil level.

6.7.4.6 [●] If specified, provisions for locally disconnecting bearing temperature sensors' wiring within the bearing housing shall be provided.

6.7.4.7 Oil flow control orifices used within the housing shall be replaceable and identified on contractual drawings.

6.7.4.8 To prevent the buildup of potential voltages in the bearing housing, residual magnetism of the free air gauss level shall not exceed ±4 gauss when measured with a calibrated Hall effect probe.

6.8 Dynamics

6.8.1 General

NOTE Refer to API 684 for more information on rotordynamics.

6.8.1.1 In the design of rotor-bearing systems, consideration shall be given to all potential sources of excitation and force such as, but not limited to, the following:

a) unbalance in the rotor system;

b) fluid forces from bearings, seals, and aerodynamics;

c) internal rubs;

d) blade, vane, nozzle, and diffuser passing frequencies;

e) gear-tooth meshing and side bands;

f) coupling misalignment;

g) loose rotor-system components;

h) internal friction within the rotor assembly;

i) synchronous excitation from complimentary geared elements;

j) control loop dynamics such as those involving AMBs;

k) driver-induced dynamics.

NOTE 1 The frequency of a potential source of excitation or force can be less than, equal to, or greater than the rotational speed of the rotor.

NOTE 2 When the frequency of a periodic forcing phenomenon (excitation) applied to a rotor-bearing support system coincides with a natural frequency of that system, the system will be in a state of resonance. A rotor-bearing support system in resonance can have the magnitude of its normal vibration amplified. The magnitude of amplification and, in the case of critical speeds, the rate of change of the phase-angle with respect to speed, is related to the amount of damping in the system.

6.8.1.2 Resonances of structural support systems that are within the vendor's scope and that affect the rotor vibration amplitude shall not occur within the specified operating speed range or the required separation margins (SM_r) (see 6.8.2.9).

6.8.1.3 The dynamic characteristics of the structural support shall be considered in the analysis of the rotor-support system [see 6.8.2.4 d)].

6.8.1.4 The vendor with unit responsibility shall communicate the existence of any undesirable running speeds in the range from zero to 150 % N_{mc}.

6.8.1.5 These undesirable running speeds shall be illustrated by the use of a Campbell diagram, submitted to the purchaser for review, and included in the instruction manual [see vendor drawing and data requirements (VDDR) in Annex B of the applicable part].

NOTE 1 Examples of undesirable running speeds are those associated with rotor lateral critical speeds with amplification factors (AFs) greater than or equal to 2.5, train torsionals, and vane and blading modes.

NOTE 2 See Annex C for examples of Campbell diagrams.

6.8.1.6 Lateral and stability analyses specified in 6.8.2 through 6.8.5 shall be reported per 6.8.1.6.1 through 6.8.1.6.3 and Annex B.

6.8.1.6.1 The standard rotordynamics report shall be provided (see B.1).

6.8.1.6.2 [●] If specified, the data requirements identified for independent audit of the results shall be provided.

6.8.1.6.3 [●] If specified, provisions shall be made to provide the purchaser with access to drawings to develop independent models of the rotor, bearings, and seals.

6.8.1.6.4 These data shall be made available in electronic format.

6.8.1.7 Torsional analysis requirements specified in 6.8.6 shall conform to 6.8.1.7.1 through 6.8.1.7.4 and Annex C.

6.8.1.7.1 The torsional reports shall be provided as described in Annex C.

6.8.1.7.2 [●] If specified, the data requirements identified for independent audit of the results shall be provided.

6.8.1.7.3 [●] If specified, provisions shall be made to provide the purchaser with access to drawings to develop independent models of the rotors.

6.8.1.7.4 These data shall be made available in electronic format.

6.8.2 Lateral Analysis

6.8.2.1 Critical speeds and their associated AFs shall be determined by means of a damped unbalanced rotor response analysis.

6.8.2.2 The vendor shall conduct an undamped analysis to identify the undamped critical speeds and determine their mode shapes.

6.8.2.3 The analysis shall identify the first four undamped critical speeds and cover as a minimum the stiffness range to produce free-free to rigid support rotor modes.

6.8.2.4 The lateral analysis shall include, but not be limited to, the following:

a) rotor stiffness, mass and polar and transverse moments of inertia, including coupling halves, and rotor stiffness changes due to shrunk on components;

b) bearing lubricant-film stiffness and damping values including changes due to speed, load, minimum to maximum preload, range of oil inlet temperature and pressure, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetrical loading that may be caused by gear forces (including the changes over range of maximum to minimum torque), side streams, eccentric clearances, volutes, etc.;

c) for tilt-pad bearings, the pad pivot stiffness;

d) structure stiffness, mass, and damping characteristics, including effects of excitation frequency over the required analysis range; for machines whose dynamic structural stiffness values are less than or equal to 3.5 times the maximum bearing stiffness value at N_{mc}, the structure characteristics shall be incorporated as an adequate dynamic system model, calculated frequency dependent structure stiffness and damping values (impedances), or structure stiffness and damping values (impedances) derived from modal or other testing; the vendor shall state the structure characteristic values used in the analysis and the basis for these values (for example, modal tests of similar rotor structure systems or calculated structure stiffness values);

e) rotational speed, including the various starting-speed detents, operating speed and load ranges (including agreed test conditions if different from those specified), trip speed, and coastdown conditions;

f) the influence, of the casing shaft end oil seals over the operating range; minimum and maximum stiffness shall be considered taking into account the tolerance on the component clearance and the oil inlet temperature;

g) the location and orientation of the radial vibration probes that shall be the same in the analysis as in the machine;

h) squeeze film damper mass, stiffness and damping values considering the component clearance and centering tolerance, oil inlet temperature range, and operating eccentricity;

i) the vendor shall state the bearing stiffness and damping values used for the analysis; the basis for these values or the assumptions made in calculating the values shall be presented;

j) dry gas seals shall be assumed to have no stiffness or damping;

k) the influence over the operating range of the damper seal’s stiffness and damping considering the tolerance on the component’s clearance and operating conditions.

6.8.2.5 [●] If specified, the vendor with unit responsibility shall provide a train lateral analysis.

6.8.2.6 The vendor with unit responsibility shall provide a train lateral analysis for machinery trains with rigid couplings.

6.8.2.7 A separate damped unbalanced response analysis shall be conducted within the speed range of 0 to 150 % of N_{mc}.

6.8.2.7.1 Unbalance shall analytically be placed at the locations defined in Figure 2.

6.8.2.7.2 For the translatory (symmetric) modes, the unbalance shall be based on the sum of the journal static loads.

6.8.2.7.3 For conical (asymmetric) modes, these unbalances shall be 180° out of phase and of a magnitude based on the static load on the adjacent bearing.

6.8.2.7.4 For overhung modes, the unbalances shall be based on the overhung mass.

6.8.2.7.5 Figure 2 shows the typical mode shapes and indicates the location and definition of U_a for each of the shapes. The magnitude of the unbalances shall be 2 times the value of U_r as calculated by Equation (3).

In SI units:

$$U_r = 6350 \frac{W}{N_{mc}} \quad \text{(for } N_{mc} < 25{,}000 \text{ rpm)} \tag{3a}$$

$$U_r = \frac{W}{3.937} \quad \text{(for } N_{mc} \geq 25{,}000 \text{ rpm)}$$

In USC units:

$$U_r = 4 \frac{W}{N_{mc}} \quad \text{(for } N_{mc} < 25{,}000 \text{ rpm)} \tag{3b}$$

$$U_r = \frac{W}{6250} \quad \text{(for } N_{mc} \geq 25{,}000 \text{ rpm)}$$

where

U_a is the input unbalance for the unbalance response analysis, in g-mm (oz-in.)

$= 2 \times U_r$;

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

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

W is the journal static load in kg (lbf), 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 (lbf) (see Figure 2).

NOTE Above 25,000, the limit is based on 0.254 µm (10 µin.) mass displacement, which is in general agreement with the capabilities of conventional balance machines, and is necessary to invoke for small rotors running at high speeds.

6.8.2.7.6 For coupling unbalance placement (unbalance based on the coupling half weight), the unbalance shall be 2 times the maximum of the following assembly check balance values:

$$U_{ac1} = \frac{K_1 \times W}{N_{mc}} \tag{4a}$$

$$U_{ac2} = K_2 \times W \tag{4b}$$

$$U_{ac3} = K_3 \tag{4c}$$

where

K_1 = 63,500 (40);

K_2 = 12.7 (0.008);

K_3 = 72 (0.1);

U_{ac} is the coupling unbalance used in the response analysis, in g-mm (oz-in.);

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

W is the mass portion of the respective coupling end in kg (lbm) (see Figure 2).

6.8.2.7.7 For rotors with damper seals, an unbalance response with and without the effects of the damper seal shall be provided.

6.8.2.8 Additional analyses shall be made for use with the verification test specified in 6.8.3.

6.8.2.8.1 The location of the unbalance shall be determined by the vendor.

6.8.2.8.2 Any test stand parameters that influence the results of the analysis shall be included.

6.8.2.8.3 For coupling unbalance placement (unbalance based on the coupling half weight), the unbalance shall not be less than 2 times or greater than 8 times the maximum value of Equation (4).

NOTE For most machines, there will only be one plane readily accessible for the placement of an unbalance; for example, the coupling flange on a single ended drive machine, or the impeller hub or disk on an integrally geared machine, or expander-compressors. However, some compressor types (axial compressors, for example) can provide additional externally accessible balance planes.

6.8.2.8.4 For other unbalance placement, the unbalance shall not be less than 2 times or greater than 8 times the maximum value of Equation (3).

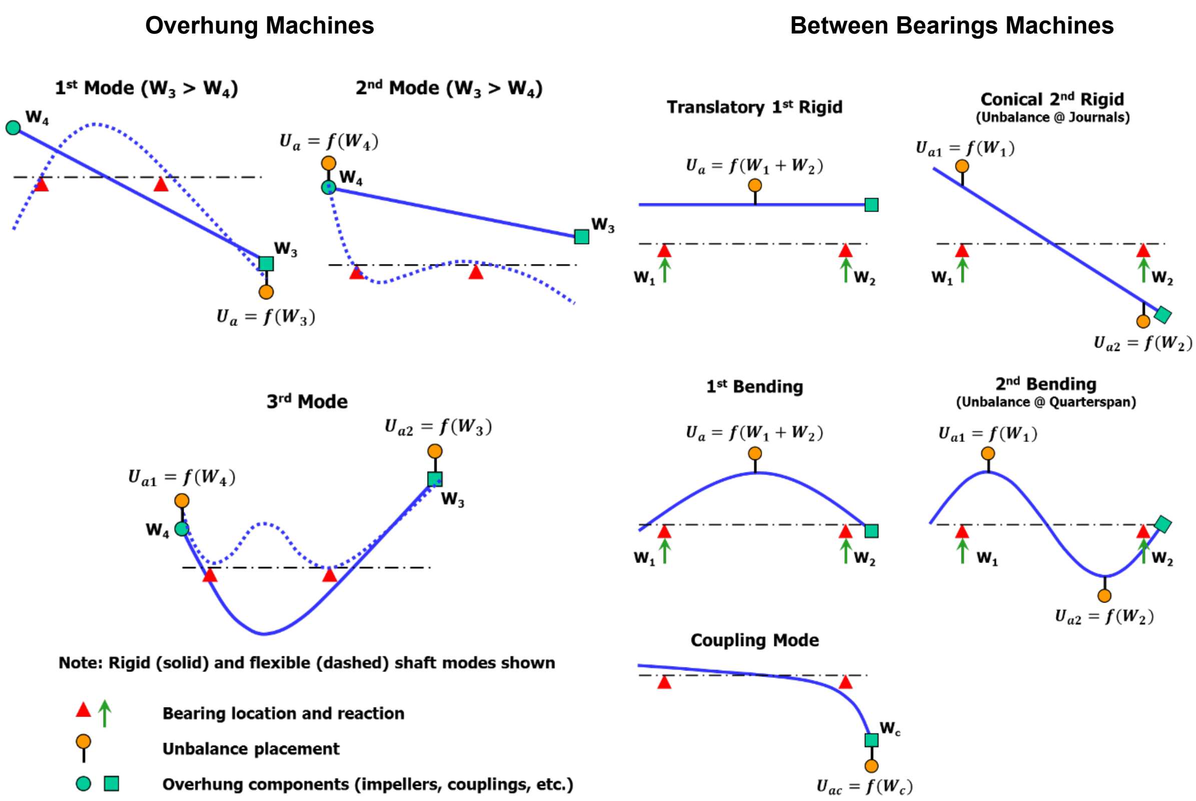


Figure 2—Typical Mode Shapes and Corresponding Unbalance

6.8.2.9 The damped unbalanced response analysis shall indicate that the machine meets the following requirement:

$$SM_a \geq SM_r \tag{5}$$

where

SM_r is the required separation margin, %;

SM_a is defined in Figure 3.

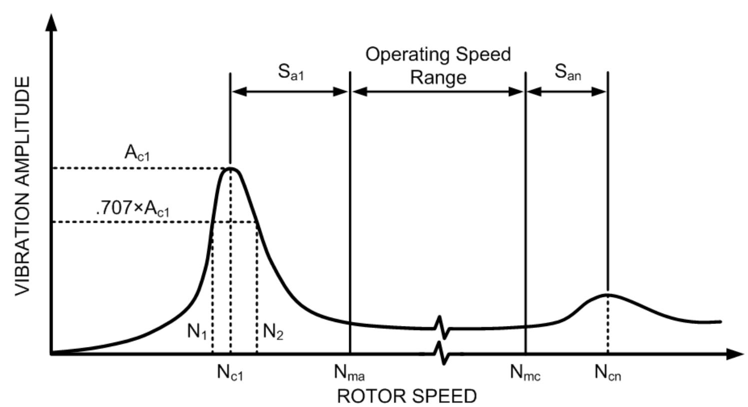
a) If the AF at a particular critical speed is less than 2.5, the response is considered critically damped and no separation margin is required ($SM_r = 0$).

b) If the AF at a particular critical speed is greater than or equal to 2.5 and that critical speed is below the minimum speed, the SM_r is given by Equation (6).

$$SM_r = 17\left(1 - \frac{1}{\mathrm{AF} - 1.5}\right) \tag{6}$$

c) If the AF at a particular critical speed is greater than or equal to 2.5 and that critical speed is above the N_{mc}, the SM_r is given by Equation (7).

$$SM_r = 10 + 17\left(1 - \frac{1}{\mathrm{AF} - 1.5}\right) \tag{7}$$



N_{c1} = Rotor first critical speed
N_{cn} = n^{th} critical speed
N_{ma} = Minimum allowable speed
N_{mc} = Maximum continuous speed

A_{c1} = Amplitude at N_{c1}
N_1 = Initial (lesser) speed at $0.707 \times A_{c1}$
N_2 = Final (greater) speed at $0.707 \times A_{c1}$
AF_1 = Amplification factor of the first critical speed
$= N_{c1} / (N_2 - N_1)$

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

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

Figure 3—Typical Rotor Response Plot

6.8.2.10 The calculated unbalanced peak-to-peak response at each vibration probe, for each unbalance amount and case as specified in 6.8.2.7, shall not exceed the mechanical test vibration limit, A_{vl}, of [25.4 µm (1.0 mil) or Equation (8), whichever is less] over the range of N_{ma} to N_{mc} as shown in Figure 4.

In SI units:

$$A_{vl} = 25.4\sqrt{\frac{12{,}000}{N_{mc}}} \tag{8a}$$

In USC units:

$$A_{vl} = \sqrt{\frac{12{,}000}{N_{mc}}} \tag{8b}$$

where

A_{vl} is the mechanical test vibration limit, µm (mil);

N_{mc} is the maximum continuous speed (rpm).

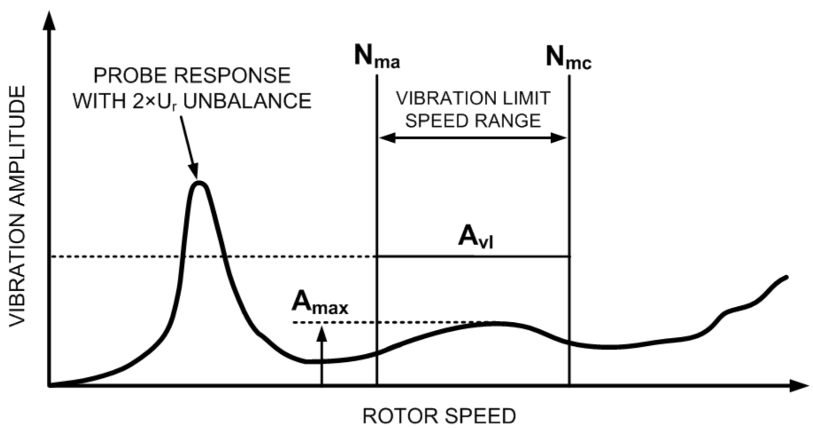


Figure 4—Plot of Applicable Speed Range of Vibration Limit

6.8.2.11 For each unbalance amount and case as specified in 6.8.2.7, the calculated major-axis, peak-to-peak response amplitudes at each close clearance location shall be multiplied by a scale factor defined by Equation (9).

$$S_{cc} = A_{vl} / A_{max} \text{ or 6, whichever is less} \tag{9}$$

where

S_{cc} is the scale factor for close clearance check;

A_{vl} is the mechanical test vibration limit defined in 6.8.2.10;

A_{max} is the maximum probe response amplitude (p-p) considering all vibration probes, over the range of N_{ma} to N_{mc}, for the unbalance amount/case being considered.

NOTE To meet the requirements of 6.8.2.10, the scale factor will be greater than or equal to one.

6.8.2.11.1 For each close clearance location, the scaled response shall be less than 75 % of the minimum design diametral running clearance over the range from zero to trip speed.

6.8.2.11.2 Running clearances can be different than the assembled clearances with the machine shutdown. Consideration should be given to:

a) centrifugal/thermal growth;

b) bearing lift;

c) rotor sag;

d) nonconcentricity (of stator to the bearings).

6.8.2.11.3 For this evaluation, floating-ring, abradable, and compliant seals are not considered close clearance locations. The response amplitude as compared to the running clearance at these locations shall be agreed.

6.8.2.12 If the analysis indicates that either of the following requirements cannot be met, a) the required separation margins and b) the requirements of 6.8.2.10 or 6.8.2.11, and the purchaser and vendor have agreed that all practical design efforts have been exhausted, then acceptable amplitudes, separation margins, and AFs shall be agreed by the purchaser and the vendor.

6.8.3 Unbalanced Rotor Response Verification Test

6.8.3.1 An unbalanced rotor response test shall be performed as part of the mechanical running test (see 8.3.5 of Part 1, 8.3.2 of Part 2, 8.3.2 of Part 3, and 8.4.3 of Part 4, whichever is applicable).

6.8.3.1.1 These results shall be used to verify the analytical model.

6.8.3.1.2 The actual response of the rotor on the test stand to the same arrangement of unbalance and bearing loads as was used in the analysis specified in 6.8.2.8 shall be used for determining the validity of the damped unbalanced response analysis.

6.8.3.1.3 To accomplish this, the requirements of 6.8.3.1.4 through 6.8.3.1.13 shall be followed.

NOTE API 684 contains discussions related to verification testing performed in a balance bunker.

6.8.3.1.4 During the mechanical running test, the amplitudes and phase angle of the shaft vibration from trip to slow roll speed shall be recorded before and after the 4-hour run.

6.8.3.1.5 The recording instrumentation resolution shall be at least 1.25 μm (0.05 mils).

NOTE This set of readings is normally taken during a coastdown, with convenient increments of speed such as 50 rpm. Since at this point the rotor is balanced, any vibration amplitude and phase detected can be the result of residual unbalance and mechanical and electrical runout.

6.8.3.1.6 The unbalance that was used in the analysis performed in 6.8.2.8 shall be added to the rotor in the location used in the analysis.

6.8.3.1.7 The machine, after being held at maximum continuous speed until bearing temperatures and radial vibrations have stabilized, shall be brought up to trip speed.

NOTE Temperature and vibration stabilization can be assumed if changes are less than 1.0 °C (2 °F) and < 10 % of vibration limit over 10 minutes for constant oil inlet conditions, respectively.

6.8.3.1.8 The indicated vibration amplitudes and phase shall be recorded during the coastdown using the same procedure as 6.8.3.1.4.

6.8.3.1.9 The location of critical speeds below the trip speed shall be established.

6.8.3.1.10 If a clearly defined response peak is not observed during the test, then the critical speeds shall be identified as those in the lateral damped analysis report.

NOTE Slow roll run out is normally vectorially subtracted from the 1X Bode plots to accurately define the location of the critical speeds.

6.8.3.1.11 The corresponding indicated vibration data taken in accordance with 6.8.3.1.4 and 6.8.3.1.8 shall be vectorially subtracted.

6.8.3.1.12 Slow roll runout shall be checked prior to subtraction.

NOTE The slow roll runout data are expected to be nearly identical for both runs.

6.8.3.1.13 The results of the mechanical run including the unbalance response verification test shall be compared with those from the analytical model specified in 6.8.2.8.

NOTE It is necessary for probe orientation to be the same for the analysis and the machine for the comparison to be valid.

6.8.3.2 [●] If specified, the unbalance verification test shall be performed in an operation speed balance bunker utilizing the agreed placement of the unbalance weight and vibration readings.

6.8.3.3 Using the unbalance response test results, the vendor shall correct the model if it fails to meet either of the following criteria:

a) the actual critical speed(s) determined on test shall not deviate from the corresponding critical speed ranges predicted by analysis by more than ±5 %;

b) at N_{mc}, the probe responses from the results of 6.8.3.1.11 shall not exceed the predicted range.

6.8.3.4 The vendor shall determine whether the comparison made is for absolute or relative motion.

NOTE For absolute motion, bearing housing vibration will need to be vectorially added to relative probe readings.

6.8.3.5 The verification test of the rotor unbalance shall be performed only on the first rotor tested, if multiple identical rotors are purchased.

6.8.3.6 After correcting the model, if required, the response shall be checked against the limits specified in 6.8.2.9 through 6.8.2.11.

6.8.3.7 The vendor shall explain how the model was corrected.

6.8.4 Stability Analysis

6.8.4.1 A stability analysis shall be performed on all centrifugal, axial compressors, or radial flow rotors that meet either of the following:

a) those rotors whose N_{mc} is greater than the first undamped critical speed on rigid supports (FCSR) in accordance with 6.8.2.3;

b) those rotors with fixed geometry bearings or oil film ring seals.

6.8.4.2 The stability analysis shall be calculated at the API defined N_{mc}.

6.8.4.3 The model used in the stability analysis shall include the items listed in 6.8.2.4.

6.8.4.4 When tilt pad journal bearings are used, the analysis shall be performed with synchronous tilt pad coefficients.

6.8.4.5 For rotors that have quantifiable external radial loading (e.g. integrally geared compressors), the stability analysis shall also include the external loads associated with the operating conditions defined in 6.8.4.7.

6.8.4.6 For some rotors, the unloaded (or minimal load condition) may represent the worst stability case and shall be considered.

6.8.4.7 The anticipated cross coupling, Q_A, present in the rotor is defined by the following procedures.

For centrifugal compressors:

The parameters in Equation (10) shall be determined based on the machine conditions at normal operating point unless the vendor and purchaser agree upon another operating point.

$$q_a = \frac{(\mathrm{HP})B_c C}{D_c H_c N_r}\left(\frac{\rho_d}{\rho_s}\right) \tag{10}$$

where

- HP is the rated power per impeller, Nm/s (hp);
- B_c is 3;
- C is 9.55 (63);
- ρ_d is the discharge gas density per impeller, kg/m^3 (lbm/ft^3);
- ρ_s is the suction gas density per impeller, kg/m^3 (lbm/ft^3);
- D_c is the impeller diameter, mm (in.);
- H_c is the minimum of diffuser or impeller discharge width per impeller, mm (in.);
- N_r is the normal operating speed for calculation of aerodynamic excitation (rpm);
- q_a is the cross coupling for each individual impeller, kN/mm (klbf/in.).

Equation (10) is calculated for each impeller of the rotor. Q_A is equal to the sum of q_a for all impellers.

For axial flow rotors:

$$q_a = \frac{(\mathrm{HP})B_t C}{D_t H_t N_r} \tag{11}$$

where

B_t is 1.5;

D_t is the blade pitch diameter, mm (in.);

H_t is the effective blade height, mm (in.).

Equation (11) is calculated for each blade row of the rotor. Q_A is equal to the sum of q_a for all stages.

6.8.4.8 Consideration should be given to all potential sources of excitation in the stability analysis, such as, but not limited to, the following:

a) labyrinth seals;

b) damper seals;

c) impeller/blade flow aerodynamic effects;

d) internal friction.

6.8.4.9 The vendor shall state how the sources are handled in the analysis.

6.8.4.10 The stability analysis shall be calculated at N_{mc}.

6.8.4.11 The operating conditions defined for the normal operating point shall be extrapolated to N_{mc} within the operating map.

6.8.4.12 The dynamic coefficients of the labyrinth seals shall be calculated at the minimum and maximum expected seal operating clearance.

6.8.4.13 When calculating the dynamic coefficients of damper seals, the operating clearance profile range, which is determined by drawing dimensions, manufacturing tolerances, and deformations in the seal, seal support, and rotor, shall be included.

6.8.4.14 The frequency and log decrement of the first forward damped mode shall be calculated progressively for the following configurations (except for double overhung machines where the first two forward modes shall be considered):

a) rotor, oil film seals, and support system only (basic log decrement, δ_b);

b) each source from 6.8.4.8 utilized in the analysis;

c) for damper seals, the dependence due to parameters defined in 6.8.4.13;

d) complete model including all sources (final log decrement, δ_f).

6.8.4.15 A sensitivity analysis shall be performed for configuration a) in 6.8.4.14 with a varying amount of cross coupling introduced at the rotor mid-span for between bearing rotors or at the center of gravity of the stage or impeller for single overhung rotors.

6.8.4.15.1 For double overhung rotors, the cross coupling shall be placed at each stage or impeller concurrently.

6.8.4.15.2 This shall reflect the ratio of the anticipated cross coupling (q_a, calculated for each impeller or stage).

6.8.4.15.3 The applied cross coupling shall extend from zero to that required to produce a zero log decrement (see Figure B.2).

6.8.4.15.4 The anticipated cross coupling, Q_A, shall be plotted.

6.8.5 Stability Acceptance Criteria

6.8.5.1 The stability analysis shall indicate that the machine, as calculated in 6.8.4.14 d), shall have a final log decrement, δ_f, greater than 0.1.

6.8.5.2 If after all practical design efforts have been exhausted to achieve the requirements of 6.8.5.1, acceptable levels of the log decrement, δ_f, shall be agreed.

6.8.5.3 [●] If specified, a stability test, to measure damping ratio (and to determine the corresponding log decrement), shall be performed as specified by the purchaser.

6.8.6 Torsional Analysis

6.8.6.1 For trains including motors, generators, positive displacement units, or gears, the vendor having unit responsibility shall ensure that a torsional vibration analysis of the complete coupled train is carried out and be responsible for directing any modifications necessary to meet the requirements of 6.8.6.3 through 6.8.6.8.

6.8.6.2 [●] If specified, for direct driven turbine trains, the vendor shall perform a torsional vibration analysis of the complete coupled train and be responsible for directing any modifications necessary to meet the requirements of 6.8.6.3 through 6.8.6.8.

6.8.6.3 A simplified torsional model (lumped rotor inertia and stiffness) is sufficient for direct driven turbine trains.

NOTE The intent of the simplified analysis is to calculate the primary (coupling) modes of the system. Primary modes are those influenced predominantly by the coupling torsional stiffness.

6.8.6.4 The torsional analysis shall include, but not be limited to, the following:

a) torsional stiffness and inertia of built-up shafts, crankshafts, and webbed shafts;

b) effects of operating temperature on material properties;

c) calculation and distribution of polar mass moment of inertia;

d) nonlinear effects from sources such as:

   1) elastomeric or torque limiting couplings;

   2) gear mesh backlash;

   3) coupling torsional stiffness boundary;

   4) electromechanical stiffness and damping in motor/generator air-gap;

   5) gear tooth stiffness;

   6) fluid drive behavior;

e) penetration factor effects on torsional stiffness due to:

   1) shaft diameter changes;

   2) keyways;

   3) shrink fits;

   4) bolted assemblies;

f) damping from sources such as:

   1) material and frictional damping within assemblies;

   2) fluid/viscous devices.

6.8.6.5 Excitation of torsional natural frequencies may come from many sources 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) torsional pulsations due to gear radial vibrations;

c) cyclic process impulses;

d) torsional excitation resulting from electric motors and engines;

e) one- and two-times electrical line frequency;

f) one- and two-times operating speed(s).

6.8.6.6 Primary (coupling) modes shall be at least 10 % above or 10 % below the 1X electrical excitation frequency.

6.8.6.7 The intersection of the primary (coupling) modes with the 1X mechanical excitation shall be at least 10 % above or 10 % below the specified operating speed range from N_{ma} to N_{mc}.

6.8.6.7.1 If torsional resonances are calculated to fall within the margin specified in 6.8.6.7 (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 steady-state stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train.

6.8.6.7.2 The analysis shall show that all shaft sections, couplings, and gear mesh have infinite life using agreed criteria.

6.8.6.8 The intersection of all other torsional natural frequencies with any possible excitation frequency should be at least 10 % above or 10 % below the specified operating speed range from N_{ma} to N_{mc}.

6.8.6.9 For synchronous motor driven units without AFD, in addition to the torsional analyses required in 6.8.6.3 through 6.8.6.8, the vendor shall perform a transient torsional vibration analysis.

6.8.6.9.1 In addition to the parameters used to perform the torsional analysis specified in 6.8.6.5, the following characteristics shall be included:

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

b) load torque vs speed;

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

6.8.6.9.2 The analysis shall generate the maximum torque as well as a torque vs time history for each of the shafts in the compressor train.

NOTE The maximum torques are used to evaluate the peak torque capability of coupling components, gearing, and interference fits of components such as coupling hubs. The torque vs time history is used to develop a cumulative damage fatigue analysis of shafting, keys, and coupling components.

6.8.6.9.3 Fatigue properties and stress concentrations shall be used.

6.8.6.9.4 A cumulative fatigue algorithm shall be used to develop a value for the safe life time number of starts.

6.8.6.9.5 [●] The required life time number of starts shall be specified by the purchaser for synchronous motor driven units.

6.8.6.10 For AFD driven equipment trains, the vendor shall extend the analysis defined in 6.8.6.3 through 6.8.6.8 to include the following.

6.8.6.10.1 In addition to the excitations of 6.8.6.5, the following shall also be considered but is not limited to:

a) integer orders of the drive output frequency;

b) sidebands of the pulse width modulation.

NOTE AFD produced broad band noise floor and feedback generated excitations can cause harmful torsional pulsations. Transient and/or mechanical/electrical coupled analyses can be required to understand the effects of these excitations.

6.8.6.10.2 A steady-state response analysis shall be performed from 0 to N_{mc} to quantify the effects of the AFD excitation of 6.8.6.10.1.

6.8.6.10.3 For intersections of the torsional natural frequencies and the AFD excitations occurring below 90 % of the minimum operating speed, agreed criteria shall be used to establish acceptability of the train.

6.8.6.10.4 For intersections of the torsional natural frequencies and the AFD excitations occurring within the operating speed range including the 10 % separation margins, the criteria set forth in 6.8.6.7 and 6.8.6.8 shall be used.

6.8.6.11 For motor-driven equipment and trains including an electrical generator, a transient short circuit fault analysis shall be performed in accordance with 6.8.6.11.1 through 6.8.6.11.2.

6.8.6.11.1 The following faults shall be considered but is not limited to:

a) short circuits:
   1) line-to-line;
   2) two-phase;
   3) three-phase;
   4) line-to-ground;
   5) line-to-line-to-ground;

b) synchronization (generators):
   1) single-phase;
   2) three-phase.

6.8.6.11.2 For these fault conditions, generated stresses in the shafting shall not exceed the low cycle fatigue limit, and in couplings, the torque shall not exceed the vendor's peak torque rating.

NOTE The analysis for these fault conditions assumes a onetime event. It is possible that some components identified by the analysis will need to be replaced following the fault event.

6.8.6.12 [●] If specified, alternating torques produced by automatic breaker reclosure shall be shown to have no negative impact on the intended operating life of the equipment train.

6.8.7 Low-speed Balancing

6.8.7.1 Major parts of the rotating element, such as the shaft, balancing drum, and impellers, shall be individually dynamically balanced before assembly, to Equation (3) or better.

6.8.7.2 When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half-key, in accordance with ISO 21940-32.

6.8.7.3 Keyways 180° apart, but not in the same transverse plane, shall also be filled.

6.8.7.4 The initial balance correction to the bare shaft shall be recorded.

6.8.7.5 The components mounted on the shaft (impellers, balance drum, etc.) shall also be balanced in accordance with the "half-key-convention," as described in ISO 21940-32.

6.8.7.6 The rotating element shall be sequentially multiplane dynamically balanced during assembly unless an operating speed balance is to be performed.

6.8.7.6.1 This shall be accomplished after the addition of no more than two major components.

6.8.7.6.2 Balancing correction shall only be applied to the elements added.

NOTE Minor correction of other components could be required during the final trim balancing of the completely assembled element.

6.8.7.6.3 The maximum allowable residual unbalance per plane (journal) shall be calculated per Equation (3).

6.8.7.6.4 In the sequential balancing process, any half-keys used in the balancing of the bare shaft (see 6.8.7.2) shall continue to be used until they are replaced with the final key and mating element.

6.8.7.6.5 On rotors with single keyways, the keyway shall be filled with a fully crowned half-key.

6.8.7.6.6 The weight of all half-keys used during final balancing of the assembled element shall be recorded on the Residual Unbalance Worksheet (see Annex A).

6.8.7.7 If the vendor's standard assembly procedures require the rotating element to be disassembled after final balance to allow compressor assembly (e.g. stacked rotors with solid diaphragms, compressor/expanders, and integrally geared compressors), the vendor shall, as a minimum, perform the following operations.

a) To ensure that the rotor has been assembled concentrically, the vendor shall take axial and/or radial runout readings on the tip of each element (impeller or disc) and at the shaft adjacent to each element when possible. The runout on any element shall not exceed a value agreed between the purchaser and the vendor.

b) The vendor shall balance the rotor to the limits of Equation (3), 6.8.2.7.5.

c) The vendor shall provide historical unbalance data readings of the change in balance due to disassembly and reassembly. This resulting unbalance shall not exceed two times the specified balance requirement.

d) The vendor shall conduct an analysis in accordance with 6.8.2, to predict the vibration level during testing, using an unbalance equal to that in item b), plus 2 times the average change in balance due to disassembly and reassembly as defined in item c). The results of this analysis shall show that the predicted vibration at each vibration probe over the range N_{ma} to N_{mc} shall be no greater than 2 times the requirements of 6.8.2.10.

NOTE Trim balancing in the compressor case can be done to achieve this level.

e) [●] If specified, the vendor shall record the balance readings after initial balance for the contract rotor. The rotor shall then be disassembled and reassembled. The rotor shall be check balanced after reassembly to determine the change in balance due to disassembly and reassembly. This change in balance shall not exceed that defined in 6.8.7.7 c).

6.8.7.8 The balancing of coated rotors shall comply with 6.2.2.2 and 6.2.2.3.

6.8.7.9 For a rotor that has been low speed balanced only, a low-speed residual unbalance check shall be performed in a low-speed balance machine and recorded in accordance with the Residual Unbalance Worksheet (see Annex A).

6.8.8 Operating Speed Balancing Procedure

6.8.8.1 [●] If specified, completely assembled rotating elements shall be subject to operating speed balancing.

6.8.8.2 The following information shall be provided, prior to operating speed balancing:

a) the contract rotordynamics analysis;

b) final low-speed balance records when applicable;

c) mechanical radial and axial runout checks of the rotor;

d) job and balance stand bearing details.

6.8.8.3 The rotor shall be supported in bearings of the same type and configuration as those in which it will be supported in service.

NOTE 1 Job bearings can be used if practical.

NOTE 2 Operating speed balance units run under a vacuum. Operation in a vacuum can require the need for temporary end seals.

6.8.8.4 The rotor shall be completely assembled including thrust collars with locking collars and any auxiliary equipment. Shaft end seals are not added.

6.8.8.5 The operating speed drive assembly shall be shown to have an effect less than 25 % of the balance tolerance.

NOTE In some cases, the facility drive coupling and adapter is adequate to simulate the job-coupling half moment. Occasionally, the job-coupling hub with moment simulator can be required, especially for the outboard ends of drive-through machines.

6.8.8.6 [●] If specified, two orthogonally mounted radial noncontacting vibration probes shall be mounted next to the bearings, at mid-shaft or at overhung locations as agreed by the purchaser and the vendor.

6.8.8.7 If noncontacting vibration probes have been specified, the following shall apply.

6.8.8.7.1 Structural resonance frequency of the probes and supports shall be determined after installation of the rotor and probe assemblies in the balance machine when nonstandard mounting is used (i.e. cantilevered probe holders).

6.8.8.7.2 Noncontacting probe data shall be compensated for slow roll mechanical and electrical runout.

6.8.8.7.3 The acceptance criteria and balance speeds shall be agreed between the purchaser and the vendor.

NOTE The criteria are typically based on the operating speed balance provider's experience and can be expressed in pedestal vibration, pedestal force, or residual unbalance.

6.8.8.7.4 The acceptance criteria for the readings shall be agreed.

6.8.8.8 The smallest pedestal rated for the rotor weight shall be used without pedestal stiffening engaged.

NOTE Light rotors used with larger pedestals could require a reduction of the rotor balance criteria.

6.8.8.9 Prior to operating speed balance, the complete rotor shall be low-speed balance checked in the operating speed facility.

6.8.8.10 If the measured unbalance exceeds five times the maximum allowable residual unbalance for the rotor, then the cause of the unbalance shall be identified prior to operating speed balancing.

NOTE The purpose of identifying the unbalance is to increase the possibility of the rotor successfully traversing its critical speed(s) and the likelihood of a successful balance.

6.8.8.11 Prior to balancing, the rotor residual unbalance shall be stabilized accomplished by:

a) record low-speed residual unbalance (amount and phase) before running up in speed;

b) run rotor to N_{mc}, hold for 3 minutes, and record vibration levels;

c) run rotor to trip speed plus 4 % of N_{mc}, hold for 3 minutes;

d) reduce to maximum continuous operating speed and record vibration levels;

e) reduce speed and record low-speed residual unbalance again;

f) repeat readings until the vector difference between a) and e) and between b) and d) is less than 25 % of the low-speed and high-speed balance requirements.

6.8.8.12 Balance weights (if used) shall be compatible with disk material and suitable for the operating environment.

6.8.8.13 After the rotor is balanced, repeat the final balance run with the pedestal stiffening engaged.

6.8.8.14 Upon completion of the balancing, Bode and polar plots for each pedestal velocity and noncontacting probe (if used) shall be provided for the initial run, stabilized rotor prior to balancing, and final balanced rotor with and without pedestal stiffening.

6.8.8.15 A rotor that has been operating speed balanced shall have the unbalance recorded in a low-speed balance machine.

6.8.8.15.1 No corrections shall be made to the rotor.

6.8.8.15.2 A permanent mark or part (such as a keyway) shall be used and recorded for the phase reference.

6.8.8.15.3 Low-speed balance setup, e.g. dimensions of bearing span, balance plane locations, shall be recorded.

NOTE 1 This is for future reference if a low-speed balance check is performed on the rotor after storage before installation.

NOTE 2 The operating speed balanced rotor will generally not meet the low-speed balance criteria.

6.8.9 Vibration

6.8.9.1 During the mechanical running test of the machine, assembled with the balanced rotor, operating at any speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the value from Equation (12).

In SI units:

$$A_{\mathrm{vl}} = \left[25.4\sqrt{\frac{12{,}000}{N_{\mathrm{mc}}}} \;\text{ or }\; 25.4 \right] \text{ whichever is less} \qquad (12a)$$

In USC units:

$$A_{\mathrm{vl}} = \left[\sqrt{\frac{12{,}000}{N_{\mathrm{mc}}}} \;\text{ or }\; 1.0 \right] \text{ whichever is less} \qquad (12b)$$

where

A_{vl} is the mechanical test vibration limit, µm (mil);

N_{mc} is the maximum continuous speed (rpm).

6.8.9.2 At any speed greater than the N_{mc}, up to and including the trip speed of the driver, the vibration level shall not increase more than 12.7 µm (0.5 mil) above the value recorded at the N_{mc} prior to accelerating to trip for each probe.

NOTE These limits are not to be confused with the limits specified in 6.8.3 for shop verification of unbalanced response.

6.8.9.3 Electrical and mechanical runout shall be determined by rotating the rotor through the full 360° supported in V blocks at the journal centers.

6.8.9.3.1 The combined runout, measured with a noncontacting vibration probe, and the mechanical runout, measured with dial indicators at the centerline of each probe location, shall be continuously recorded during the rotation.

6.8.9.3.2 PTFE shall not be used in the V blocks.

NOTE The rotor runout determined above generally will not be reproduced when the rotor is installed in a machine with hydrodynamic bearings. This is due to pad orientation on tilt pad bearings and effect of lubrication in all journal bearings.

6.8.9.4 Records of electrical and mechanical runout for the full 360° at each probe location shall be included in the mechanical test report (mechanical test section).

6.8.9.5 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of the level from Equation (13) or 6.35 µm (0.25 mil), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

In SI units:

$$R_{\mathrm{out}} = \frac{25.4}{4}\sqrt{\frac{12{,}000}{N_{\mathrm{mc}}}} \tag{13a}$$

In USC units:

$$R_{\mathrm{out}} = \frac{1}{4}\sqrt{\frac{12{,}000}{N_{\mathrm{mc}}}} \tag{13b}$$

6.8.9.6 Where shaft treatment such as metalized aluminum bands have been applied to reduce electrical runout, surface variations (noise) may cause a high-frequency noise component that does not have an applicable vector. The nature of the noise is always additive. In this case, the noise shall be mathematically subtracted.

6.9 Other Standard Specific Components

6.9.1 Shaft End Seals

6.9.1.1 General

6.9.1.1.1 Shaft seals and seal systems shall be provided to restrict or prevent process gas leaks to the atmosphere over the range of specified operating conditions, including start-up, shutdown, settle-out, or any other special conditions (air dry-out, etc.).

6.9.1.1.2 The shaft seals and seal system shall be designed to permit safe machine pressurization with the seal system in operation prior to process start-up.

6.9.1.1.3 [●] The purchaser shall provide the settle-out pressure.

NOTE If a value is not provided, the vendor will estimate a value that needs to be checked later against suction relief valve set pressure.

6.9.1.1.4 The maximum sealing pressure shall be at least equal to the settle-out pressure.

6.9.1.1.5 [●] Shaft seals may be one of the types described in 6.9.1.2 through 6.9.1.6, as specified.

6.9.1.1.6 Seal pressure equalizing lines and associated gas passages (including those for reference gas and axial thrust force balancing) shall be sized to maintain design shaft end seal performance at twice the maximum initial design clearances.

6.9.1.1.7 Any reference pressure measurements for pressure control systems shall be drilled directly into the upper half of the cavity.

6.9.1.1.7.1 These should be taken from ports used only for that pressure measurement to eliminate exit and entrance losses.

6.9.1.1.7.2 These ports should not be used for venting or supplying gas to the cavity.

NOTE This can be impractical on some smaller machines.

6.9.1.1.8 [●] The purchaser shall specify composition and the supply conditions (pressure and temperature) of buffer, seal, and separation gases.

6.9.1.1.9 The method of control (flow control or pressure control) and system configuration shall be agreed.

6.9.1.1.10 If buffer gas or seal gas is specified by the purchaser or required by the vendor, the vendor shall state the gas requirements, including pressures, flow rates, and filtration.

6.9.1.1.11 The vendor shall furnish the complete seal control system including schematic and bill of material.

6.9.1.1.12 For compressors with subatmospheric pressure at the shaft end seals, provision shall be made to pressurize the seal(s) with gas at a pressure that is higher than atmospheric.

6.9.1.2 Clearance Seals

6.9.1.2.1 The labyrinth seal may include carbon rings, in addition to the labyrinths, if approved by the purchaser.

6.9.1.2.2 Labyrinths may be stationary or rotating.

6.9.1.2.3 The restrictive-ring seal shall include rings of carbon or other suitable material mounted in retainers or in spacers.

6.9.1.2.4 The seal may be operated dry, with a sealing liquid, or with a buffer gas.

6.9.1.2.5 If eductors or injection systems are provided, they shall be furnished per 6.9.1.2.5.4.

6.9.1.2.5.1 Complete with piping, regulating and control valves, pressure gauges, and strainers.

6.9.1.2.5.2 Each item shall be piped and valved to permit its removal during operation of the compressor.

6.9.1.2.5.3 Where gas from the compressor discharge is used for the motivating power of the eductor, provisions shall be made for sealing during start-up and shutdown.

6.9.1.2.5.4 Instrumentation and controls shall be provided to ensure proper eductor performance under all potential motive fluid and compressor discharge pressure conditions.

NOTE Eductor performance can be sensitive to the motive and discharge pressure of the eductor.

6.9.1.3 Oil Seals

6.9.1.3.1 Shaft end oil seal(s) shall be provided with provision(s) to inject conditioned buffer gas between the seal and the process gas.

6.9.1.3.2 The leakage from each seal that contacts the process gas shall be piped to an independent drain.

6.9.1.3.3 Seal oil contaminated by the process gas that would damage components such as bearings, seal rings, O-rings, and couplings shall be piped away separately to allow disposal or reconditioning.

6.9.1.3.4 [●] If specified, and when separate lube and seal oil is required, the uncontaminated oil drain shall be separate from the bearing housing oil drain with an internal seal with buffer provision provided to prevent oil cross contamination.

6.9.1.4 Mechanical Contact Seals

6.9.1.4.1 The mechanical contact seal shall be provided with labyrinths and slingers.

6.9.1.4.2 Oil or other suitable liquid furnished under pressure to the rotating seal faces may be supplied from the lube-oil system or from an independent seal system.

6.9.1.4.3 Mechanical seals shall be designed to minimize gas leaks while the compressor is pressurized and being shut down and after it is stopped in the event of seal-oil failure.

6.9.1.4.4 The seal shall be provided with a device to provide sealing while shutdown and when oil pressure is not applied.

6.9.1.5 Liquid Film Seal

6.9.1.5.1 The liquid-film seal shall be provided with sealing rings or bushings and labyrinths. Liquid-film seals may be cylindrical-bushing seal or pumping seals.

6.9.1.5.2 An elevated tank shall be provided with the required static head to overcome system pressure losses (such as friction losses in internal passages and seal-oil piping) to maintain positive sealing pressure.

6.9.1.5.2.1 The vendor shall state the height of the tank reference mark above the compressor centerline.

6.9.1.5.2.2 Other means to maintain this differential pressure and positive seal may be used with the purchaser's approval.

6.9.1.6 Dry Gas Seal

NOTE 1 Refer to API 692, Part 2, Annex C for dry gas seal nomenclature.

NOTE 2 Refer to API 692, Part 3, Annex A for dry gas seal support system datasheets.

6.9.1.6.1 Dry gas seals shall be in accordance with API 692, Parts 1 and 2.

6.9.1.6.2 Seal support systems for dry gas seals shall be in accordance with API 692, Parts 1 and 3.

6.9.1.6.3 Seal vents and drains shall conform to the following.

a) Seal cavities shall be designed to keep liquid from the dry gas seals. Drains shall be located in the bottom of all seal cavities to fully drain the cavity.

b) The compressor vendor shall define the sizing criteria (pressure drop and maximum flow) for primary and secondary vents.

c) Drain sizing shall be such to prevent blockage of the line.

NOTE There can be insufficient space for small compressors to have dedicated drain lines.

6.9.1.6.4 Pins or keys shall be replaceable without compressor disassembly other than seal cartridge removal.

6.9.2 Integral Gearing

For units with integral gears, see Part 3.

6.9.3 Nameplates and Rotation Arrows

NOTE Additional information regarding nameplates and rotational arrows can be found in Parts 2, 3, and 4 as applicable.

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

6.9.3.2 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper (UNS N04400) alloy.

6.9.3.2.1 Attachment pins shall be of the same material.

6.9.3.2.2 Welding to attach the nameplate to the casing is not permitted.

6.9.3.3 Where speed requires adjustment as a result of performance testing, the nameplate shall reflect these values.

6.9.3.4 Rated power on the nameplate may be the calculated value provided the tested rated power is within allowable tolerances.

6.9.3.5 [●] SI or USC units shall be specified for use on the nameplate.

6.9.3.6 Lateral critical speeds exhibited during the running tests shall be stamped on the nameplate followed by the word “test.”

6.9.3.7 Lateral critical speeds predicted by calculation up to and including the critical speed above trip speed and not identifiable by test shall be stamped on the nameplate followed by the abbreviation “calc.”

7 Accessories

7.1 Lubrication and Sealing Systems

7.1.1 A pressurized oil system or systems shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the following:

a) the bearings of the driver and of the driven equipment (including the gear mesh);

b) the governing and control-oil driven actuators;

c) the shaft oil seals;

d) the purchaser’s control system (if hydraulic).

7.1.2 Pressurized oil systems shall conform to the requirements of API 614, for unspared equipment in critical service.

7.2 Mounting Fixtures

7.2.1 Soleplate or Baseplate

7.2.1.1 General

7.2.1.1.1 [●] The equipment shall be furnished with soleplates or a baseplate, as specified.

7.2.1.1.2 Baseplates and soleplates shall comply with the requirements of 7.2.1.2.1 through 7.2.1.2.18.

7.2.1.2 General

7.2.1.2.1 Soleplate or baseplate shall be furnished with horizontal (axial and lateral) jackscrews meeting the following requirements.

a) The lugs holding these jackscrews shall be attached to the soleplate or baseplate in such a manner that they do not interfere with the installation of the equipment, jackscrews, or shims.

b) Means for moving the equipment vertically for removal or insertion of shims shall be provided.

c) Vertical jackscrews (if provided) in the equipment feet shall not mar the shimming surfaces.

d) Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of lateral and axial jackscrews provided on the soleplate or baseplate.

e) Alternative methods of lifting the equipment for the removal or insertion of shims or for moving the equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed.

f) Alignment jackscrews shall be plated for rust resistance.

g) Materials used for plating shall not create a galvanic reaction between the plating material and the parent material.

7.2.1.2.2 The alignment shims shall be provided by the vendor in accordance with API 686, Chapter 7 and meet the following requirements.

a) Each shall straddle the hold-down bolts and vertical jackscrews.

b) Shims shall be at least 6 mm (0.25 in.) larger on all sides than the equipment feet.

7.2.1.2.3 All machinery mounting surfaces on the soleplate or baseplate shall be machined flat and parallel to the axial plane(s) of the machinery.

7.2.1.2.3.1 Mounting feet after fabrication shall extend at least 25 mm (1 in.) beyond the outer three sides of the equipment feet.

7.2.1.2.3.2 These mounting surfaces shall meet the following requirements.

a) Each mounting surface shall be machined to a finish of 6 μm (250 μin.) Ra or better.

b) To prevent a soft foot, when the machine is installed on the soleplate or baseplate, all mounting surfaces in the same horizontal plane shall be within 125 μm (0.005 in.).

c) Each mounting surface shall be machined within a flatness of 75 μm per linear m (0.001 in. per linear ft) of mounting surface.

d) Different mounting planes shall be parallel to each other within 125 μm (0.005 in.).

7.2.1.2.4 Machinery soleplates, baseplates and supports shall be designed to have sufficient strength and rigidity to limit coupling movement (caused by imposing allowable forces and moments) to 50 μm (0.002 in.).

NOTE Refer to Parts 2, 3, or 4 as applicable for allowable piping loads.

7.2.1.2.5 Anchor bolts shall be furnished by the purchaser.

7.2.1.2.6 Anchor bolts shall not be used to fasten machinery to the soleplate or baseplate unless approved by the purchaser.

7.2.1.2.7 Grouted soleplates or baseplates shall be sized to limit the static loading to 700 kPa (100 psi) on the grout.

7.2.1.2.8 Diametrical clearance between anchor bolts and the anchor bolt holes in the soleplates or baseplates shall be a minimum of 6 mm (0.25 in.).

7.2.1.2.9 Soleplates and baseplates shall be supplied with vertical leveling screws for field leveling.

a) A leveling screw shall be provided near each anchor bolt.

b) If the equipment and soleplate or baseplate are too heavy to be lifted using leveling screws, alternate methods shall be provided by the equipment vendor.

c) The design of the alternate method shall be included in the proposal.

7.2.1.2.10 Soleplate or baseplate surfaces that are embedded in grout shall have 50 mm (2 in.) radiused minimum outside corners (in the plan view).

7.2.1.2.11 The embedded edges shall be chamfered or rounded (see Figure 5).

7.2.1.2.12 Machinery hold-down bolts and fasteners for attaching the equipment to the mounting shall be provided by the equipment vendor.

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

7.2.1.2.14 [●] The purchaser shall specify the manufacturer and specific type of epoxy grout used for field installation.

7.2.1.2.15 The equipment vendor shall prepare the soleplate or baseplate by commercially abrasive blasting all grout contacting surfaces in accordance with SSPC SP 6 (ISO 8501, Grade Sa2).

7.2.1.2.16 The equipment vendor shall precoat these surfaces with a primer compatible with the specified epoxy grout.

7.2.1.2.17 The equipment vendor shall provide details of the actual epoxy primer used.

7.2.1.2.18 All mounting surfaces that are not grouted shall be coated with a rust preventive immediately after machining.

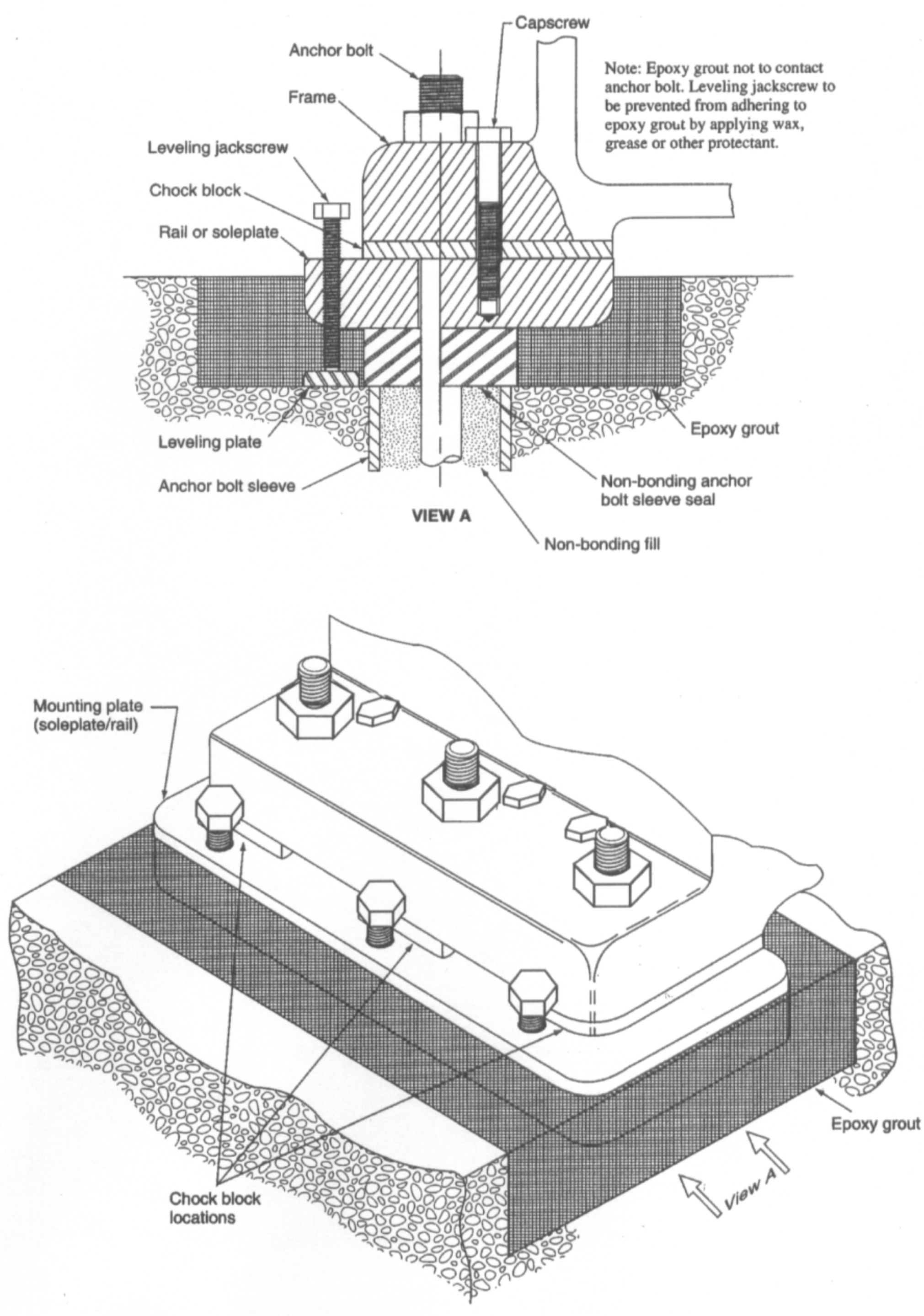


Figure 5—Typical Soleplate or Baseplate Arrangement

7.2.2 Baseplates

7.2.2.1 [●] The purchaser shall specify the major equipment mounted on the baseplate.

7.2.2.1.1 The purchaser and the vendor shall agree on the baseplate design.

7.2.2.1.2 A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor agree that it may be fabricated in multiple sections.

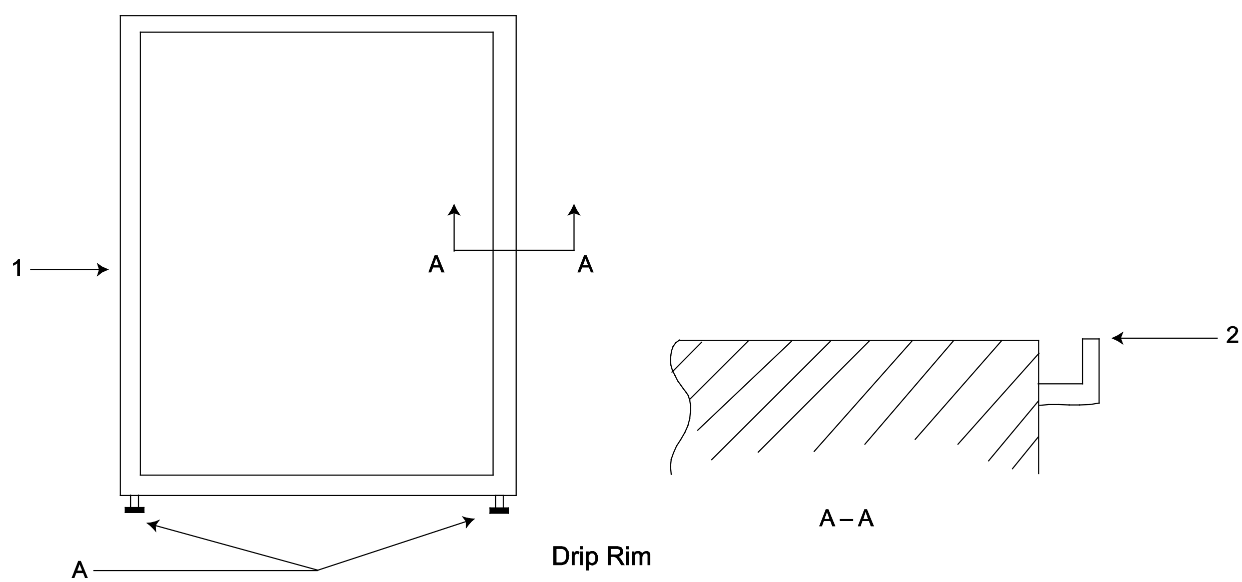
NOTE A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) can require fabrication in multiple sections because of shipping restrictions.

7.2.2.1.3 Multiple-section baseplates shall have machined and doweled mating surfaces that are bolted together to ensure required field reassembly tolerances.

7.2.2.1.4 [●] If specified, baseplates shall be equipped with a drip rim (see Figure 6).

7.2.2.1.5 One minimum drain connection of at least 40 mm (NPS 1 1/2 in.) size shall be supplied to ensure proper drainage of possible leakage of the baseplate mounted equipment.

7.2.2.1.6 All supports for machinery shall have full depth cross members located underneath.



Key

A drains

1 slope to drain

2 level with baseplate to avoid tripping hazard

Figure 6—Drip Rim

7.2.2.2 The underside mounting surfaces of the baseplate shall be in one plane to permit use of a single-level foundation.

7.2.2.3 All joints including deck plate and structural members shall be continuously seal welded to prevent crevice corrosion.

7.2.2.4 Stitch welding, top or bottom, is unacceptable.

7.2.2.5 [●] If specified, nonskid decking or grating covering all walk and work areas shall be provided on the top of the baseplate.

7.2.2.5.1 If grating is provided, it shall be removable.

7.2.2.5.2 If, after grouting, the purchaser plans to completely fill the baseplate with cement as a finished surface, decking or grating is not required.

7.2.2.5.3 Horizontal solid decked surfaces shall be sloped to avoid collection of liquid.

7.2.2.6 [●] If specified, the baseplate shall be designed for mounting on structural columns and be sufficiently rigid without continuous grouting.

NOTE Baseplate rigidity refers to static and dynamic stiffness and how these factors impact the mounted equipment.

7.2.2.7 [●] If specified, the baseplate shall be designed to facilitate the use of optical, laser, or other instruments for field leveling during installation. Design details are described in 7.2.2.9.

7.2.2.8 If leveling pads or targets are provided, the pads or targets shall be located close to the machinery support points and be accessible for field leveling with the equipment mounted and the baseplate on the foundation.

7.2.2.8.1 The leveling pads and targets shall have protective removable covers.

7.2.2.8.2 For baseplates longer than 6 m (20 ft), additional pads and targets shall be provided at intermediate points.

7.2.2.9 The baseplate shall be provided with lifting lugs for at least a four-point lift.

7.2.2.9.1 Lifting lugs attached to the equipment shall be designed using a maximum stress of one-third of the minimum yield strength of the material.

7.2.2.9.2 Baseplates shall be designed for lifting with all equipment mounted.

7.2.2.9.3 Welding applied to lifting lugs shall be continuous welds and be in accordance with AWS D1.1/D1.1M, ISO 15614, or other agreed structural welding code.

7.2.2.9.4 The welds shall be 100 % NDT in accordance with the applicable code.

7.2.2.9.5 Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the equipment mounted on it.

7.2.2.9.6 Removable lugs or commercially available specialty products such as pivot type hoisting rings can be provided with purchaser approval.

7.2.2.9.7 [●] If specified, commercially available lifting attachments shall be furnished with material and load test certifications traceable to an internationally recognized standard and attested by an independently accredited third-party agency or organization.

7.2.2.10 If the baseplate is intended for grouting onto a concrete foundation, access shall be provided into each compartment and the following met.

7.2.2.10.1 The baseplate shall be provided with at least one grout hole having a clear area of at least 125 cm^2 (20 $in.^2$). Grout holes shall have a diameter no less than 75 mm (3 in.) in each bulkhead section.

7.2.2.10.2 These grout holes shall be located to permit filling the entire cavity under the baseplate without creating air pockets.

7.2.2.10.3 The grout holes shall be accessible for grouting with the equipment installed.

7.2.2.10.4 Vent holes at least 13 mm (0.5 in.) in size shall be provided at the highest point and located to vent the entire cavity of each bulkhead section of the baseplate.

7.2.2.10.5 Metallic covers with a minimum thickness of 0.06 in. (1.5 mm, 16 gauge) shall be provided for each grout hole.

7.2.2.11 Support for the equipment shall be located directly beneath the equipment feet and extend in line vertically to the bottom of the baseplate.

7.2.2.12 [●] If specified, the bottom of the baseplate shall have machined mounting pads.

7.2.2.13 The mounting pads shall be machined in a single plane after the baseplate is fabricated.

NOTE These machined mounting pads are necessary when the baseplate is mounted on subsoleplates or structural steel members to facilitate field leveling.

7.2.2.14 Oil reservoirs shall be separate from the baseplate.

7.2.2.15 With the machine aligned on the baseplate in the shop, each hold-down bolt shall have a minimum radial clearance of 1.5 mm (0.0625 in.) between the bolt and the bolt hole.

NOTE Hold-down bolts need adequate clearance within the bolt holes so the machinery can be moved laterally during final field alignment without becoming bolt bound.

7.2.3 Soleplates and Subsoleplates

7.2.3.1 Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation.

7.2.3.2 In no case shall the plates be less than 40 mm (1.5 in.) thick.

7.2.3.3 Soleplates shall be large enough to extend beyond the feet of the equipment in all directions and be designed such that the anchor bolts are not covered by machine feet.

7.2.3.4 [●] If specified, subsoleplates shall be provided by the vendor.

7.2.3.5 If subsoleplates are used, soleplates shall be fully machined top and bottom.

7.2.3.6 [●] If subsoleplates are specified, they shall be steel plates at least 25 mm (1 in.) thick.

7.2.3.7 The finish of the subsoleplates' mating surfaces shall match that of the soleplates.

7.3 Controls and Instrumentation

7.3.1 General

7.3.1.1 The vendor shall provide machine performance data (in accordance with Section 9) and all other information as agreed to design a control system for start-up, for all specified operating conditions, for shutdown and for surge prevention.

7.3.1.2 [●] The purchaser shall specify that controls and instruments are designed for outdoor or indoor installation.

7.3.1.3 [●] The purchaser shall specify required construction and installation standards for controls.

7.3.1.4 Controls and instrumentation that are installed outdoors shall have a minimum ingress protection level of IP 65 as detailed in IEC 60529 or a NEMA 4 minimum rating per NEMA 250.

7.3.1.5 [●] Terminal boxes shall have a minimum ingress protection level of IP 66 as detailed in IEC 60529 or a NEMA 4X minimum rating per NEMA 250, as specified.

7.3.1.6 If IEC 60529 ingress protection is specified, the controls and instrumentation, equipment and wiring, and terminal boxes shall comply with the construction requirements of IEC 60079.

7.3.1.7 Terminal boxes shall be 316 SS unless otherwise agreed.

7.3.1.8 All conduit, armored cable, and supports shall be designed and installed so that they can be removed without damage.

7.3.1.9 All conduit, armored cable, and supports shall be located so that they do not hamper removal of bearings, seals, or equipment internals.

7.3.2 Control Systems

7.3.2.1 [●] The purchaser shall specify the method of control, the source of the control signal, its sensitivity and range, and the equipment furnished by the vendor.

7.3.2.2 [●] If specified, an anti-surge control system shall be provided. The scope of supply shall be agreed.

NOTE See Annex E.

7.3.2.3 [●] If specified, the vendor shall supply the anti-surge valve.

7.3.2.3.1 [●] For vendor supplied anti-surge valves, the purchaser shall specify the conditions upstream and downstream of the anti-surge valve for steady-state and transient conditions.

7.3.2.3.2 The vendor shall report the following information associated with the valve sizing and selection for purchaser's review:

a) the conditions upstream and downstream of the anti-surge valve;

b) the percent open valve position used to determine the sizing;

c) the time required to stroke the valve from full closed to full open in open and closed loop control actions.

7.3.2.3.3 The anti-surge valve shall be designed to permit operation in full recycle.

7.3.2.4 [●] If specified, the vendor shall supply a dynamic simulation with the scope and specifications as agreed (see Annex H).

7.3.3 Instrument and Control Panels

Refer to API 614 and API 692 for instrument and control panels requirements.

7.3.4 Instrumentation

Refer to API 614 and API 692 for instrumentation and API 670 for instrumentation and installation requirements.

7.3.5 Alarms, Shutdowns, and Control Systems

Refer to API 614, API 692, and API 670 on alarms, shutdowns, and control systems requirements.

7.3.6 Electrical Systems

Refer to API 614 on electrical systems requirements.

7.3.7 Vibration, Position, and Bearing Temperature Detectors

Vibration, position, and bearing temperature detectors shall be covered in 7.3 of Parts 2, 3, and 4, as applicable.

7.4 Special Tools

7.4.1 If special tools or fixtures are required to disassemble, assemble, or maintain the equipment, they shall be included in the quotation and furnished as part of the initial supply of the equipment.

7.4.2 For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be agreed between the purchaser and the vendor.

7.4.3 These special tools shall be used during shop assembly and post-test disassembly of the equipment.

7.4.4 Special tools that do not exceed 1 m (3 ft) in length, width, or height and that weigh less than 40 kg (100 lbm) shall be packaged in metal or plastic boxes and marked "special tools for (tag/item number), box x of x."

7.4.5 Each tool shall be stamped or have an attached stainless steel tag to indicate its intended use.

7.4.6 Vendor shall supply a complete list of special tools and instructions for use.

7.4.7 Larger tools shall have a stainless steel tag permanently attached to indicate both the intended use and the tag/item number of the equipment for which they are intended.

7.5 Couplings and Guards

7.5.1 The couplings shall be of the nonlubricated flexible type.

7.5.2 Couplings and guards between drivers and driven equipment shall be supplied by the manufacturer of the driven equipment.

7.5.3 Couplings, coupling to shaft junctures, and coupling guards shall conform to API 671.

7.5.4 The make, design, and mounting arrangement of the coupling shall be agreed by the purchaser and the vendor with unit responsibility of the driver and driven equipment.

7.5.5 The vendor shall coordinate the mounting of hubs.

NOTE Hubs can be mounted by equipment vendors or by others in the field if required.

7.5.6 The purchaser of the coupling shall provide or include a moment simulator, if required for the mechanical running test or operating speed balancing.

7.5.7 [●] If specified, the coupling vendor shall provide ring and plug gauges in accordance with API 671.

7.5.8 [●] The purchaser shall specify whether lapping tools are required.

7.5.9 If hydraulically fitted couplings are provided, the vendor shall provide and prove all necessary mounting tools to hydraulically remove and install each coupling.

7.6 Drivers and Gearing

7.6.1 General

7.6.1.1 [●] The driver shall be of the type specified, sized to meet the maximum specified operating conditions, including external gear or coupling losses.

7.6.1.2 The driver shall be in accordance with applicable specifications.

7.6.1.3 The driver(s) shall operate under the utility and site conditions specified.

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

7.6.1.5 The driver shall be capable of starting under the process and utility conditions specified.

7.6.1.6 The starting method and worst-case starting torque requirements shall be agreed.

7.6.2 Steam Turbine Drives

7.6.2.1 Steam turbine drivers shall conform to API 612.

7.6.2.2 Steam turbine drivers shall be sized to deliver continuously not less than 110 % of the maximum power required by the machine train, when operating at any of the specified operating conditions, and specified normal steam conditions.

7.6.2.2.1 The 110 % applies to the design phase of the project.

7.6.2.2.2 After testing, this margin may not be available due to performance tolerances of the driven equipment.

7.6.3 Motor Drives

7.6.3.1 Motor drives shall conform to 7.6.3.2 through 7.6.3.3.2.

7.6.3.2 Motors that are below the power scope of API 541 or API 546 shall be in accordance with IEEE 841.

7.6.3.3 The motor power shall be at least 110 % of the greatest power required (including gear and coupling losses) for any of the specified operating conditions.

7.6.3.3.1 The 110 % applies to the design phase of a project.

7.6.3.3.2 After testing, this margin may not be available due to performance tolerances of the driven equipment.

NOTE Refer to 8.3.5.8 of Part 2 and 8.3.4.2.3 of Part 3 for allowable tolerances for fixed-speed applications. The purchaser can specify additional motor power or removal of excess head.

7.6.4 Gas Turbine Drives

Gas turbine drivers shall conform to API 616.

7.6.5 Separate Gear Units

Separate gear units shall conform to API 613.

NOTE For integral gears in compressors, see Part 3.

7.7 Enclosures and Insulation

(Intentionally Left Blank)

7.8 Other Standard Specific Systems

7.8.1 Piping and Appurtenances

7.8.1.1 General

7.8.1.1.1 Auxiliary piping shall be in accordance with API 614 and API 692.

7.8.1.1.2 Auxiliary systems furnished shall be in accordance with API 614 and API 692, Parts 1 and 3.

7.8.1.1.3 Auxiliary piping to the machine shall have breakout spools to allow for maintenance and for removal of the entire machine.

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

NOTE Generally, this is accomplished by short spool pieces at the equipment.

7.8.1.1.5 Provision shall be made for flushing dry gas seal system interconnecting piping prior to operation.

NOTE Refer to API 692 Part 4 Annex B for cleaning/flushing of field installed piping.

7.8.2 Instrument Piping and Tubing

Instrument piping and tubing, if furnished, shall be in accordance with API 614 or API 692, whichever applies.

7.8.3 Process Piping

Process piping, if furnished, shall be in accordance with API 614.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

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

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

8.1.3 [●] The purchaser shall specify the amount of advance notification required for scheduling or postponing a witnessed or observed inspection or test.

8.1.3.1 If the testing is to be rescheduled, the vendor shall contact the purchaser within 5 working days from the cancellation notice.

8.1.3.2 The new date shall be agreed.

8.1.4 [●] The purchaser shall specify the extent of his/her participation in the inspection and testing.

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

8.1.6 Equipment, materials, and utilities required for the inspection and tests shall be provided by the vendor.

8.1.7 [●] If specified, the purchaser's representative, the vendor's representative, or both shall indicate compliance in accordance with the Inspector's Checklist (Annex D of Parts 2, 3, or 4, as applicable) by initialing, dating, and submitting the completed form before shipment.

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

8.1.9 Witnessed mechanical running or performance tests require written confirmation of a successful preliminary test.

NOTE See 8.1.3. Notification need not wait until the successful preliminary test is completed.

8.2 Inspection

8.2.1 General

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

a) necessary certification of materials, such as mill test reports, for pressure-containing parts and rotating elements;

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

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

d) results of quality control tests and inspections;

e) details of all repairs;

f) as-built assembly and maintenance clearances;

g) other data specified by the purchaser or required by applicable codes and regulations (see 5.1 and I.3.1.1);

h) purchase specifications for all major items on bills of materials.

8.2.1.2 Pressure-containing parts shall not be painted until hydro test of the parts is completed.

8.2.1.3 If a helium leak test after hydro test is required (see 8.3.7.3), 8.2.1.2 shall also apply.

8.2.1.4 [●] In addition to the requirements of 6.2.1.4, and the materials specifications, the purchaser shall specify and identify:

a) parts that shall be subject to surface and subsurface examination;

b) the type of examination required, such as magnetic particle, liquid penetrant, radiographic, or ultrasonic examination.

NOTE Material specifications contain mandated and supplemental inspections.

8.2.1.5 During assembly of the equipment, each component (including integrally cast-in passages) and all piping and appurtenances shall be inspected to ensure that they have been cleaned and are free of foreign materials, corrosion products, and mill scale.

8.2.1.6 [●] If specified, the equipment and all piping and appurtenances shall be inspected for cleanliness, before heads are welded onto vessels, openings in vessels or exchangers are closed, or piping is assembled.

8.2.1.7 [●] If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing.

8.2.1.8 The method, extent, documentation, and witnessing of the testing shall be agreed.

8.2.2 Material Inspection

8.2.2.1 General

8.2.2.1.1 [●] If radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the recommended practices in 8.2.3 through 8.2.6 shall apply unless other corresponding procedures and acceptance criteria have been specified.

8.2.2.1.2 Acceptance standards for 8.2.3 through 8.2.6 shall be agreed.

NOTE API 687 Table of Generalized NDE Acceptance Criteria can be consulted and used as a guide.

8.2.3 Radiographic Inspections

Radiography shall be based upon the procedures of ASTM E94/E94M or appropriate country codes and standards.

8.2.4 Ultrasonic Inspection

Ultrasonic inspection shall be based upon the procedures of ASTM A609 (castings), ASTM A388 (forgings), or ASTM A578 (plate), or appropriate country codes and standards.

8.2.5 Magnetic Particle Inspection

Both wet and dry methods of magnetic particle inspection shall be based upon the procedures of ASTM E709 or appropriate country codes and standards.

8.2.6 Liquid Penetrant Inspection

Liquid penetrant inspection shall be based upon the procedures of ASTM E165/E165M or appropriate country codes and standards.

8.3 Testing

8.3.1 General

8.3.1.1 Equipment shall be tested in accordance with 8.3.2 through 8.3.6.

8.3.1.2 Other tests that may be specified by the purchaser are described in 8.3.7.

8.3.2 Hydrostatic Test

8.3.2.1 Pressure casings shall be tested hydrostatically with liquid at a minimum of 1.5 times the MAWP.

8.3.2.2 The minimum hydro test pressure shall not be less than 1.5 barg (20 psig).

8.3.2.3 Tests shall be maintained for a period of time that permits a complete examination of parts under pressure.

8.3.2.3.1 The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum of 30 minutes.

8.3.2.3.2 Large, heavy castings may require a longer testing period as agreed by the purchaser and the vendor.

8.3.2.3.3 Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure is acceptable.

8.3.2.4 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 mg/kg (50 parts per million).

8.3.2.5 To prevent deposition of chlorides on austenitic stainless steel as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

8.3.2.6 The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

NOTE The nil-ductility temperature is the highest temperature at which a material experiences complete brittle fracture without appreciable plastic deformation.

8.3.2.7 Where testing of sections of a casing at different pressures is approved, a combined test shall be conducted with the appropriate pressure simultaneously in each section.

8.3.3 Impeller Overspeed Test

8.3.3.1 Each impeller shall be subjected to an overspeed test at not less than 115 % of N_{mc} for a minimum duration of 1 minute.

8.3.3.2 Impeller dimensions identified by the vendor as critical (such as bore, eye seal, and outside diameter) shall be measured before and after each overspeed test.

8.3.3.3 All such measurements and the test speeds shall be recorded and submitted for the purchaser's review following the test.

8.3.3.4 Any permanent deformation of the bore or other critical dimension outside drawing tolerances is cause for rejection of the test.

8.3.4 Dry Gas Seals

Seal support systems and testing for self-acting dry gas seals shall be in accordance with API 692.

8.3.5 Mechanical Running Test

NOTE For additional specifics regarding mechanical running tests, see Parts 2, 3, or 4, as applicable.

8.3.5.1 All contract vibration probes, cables between oscillator-demodulators and probes, oscillator-demodulators and accelerometers shall be used during the test.

8.3.5.2 Their measurements shall be the basis for acceptance.

8.3.5.3 Shop test facilities shall include the capability of continuously monitoring, displaying, recording, and printing:

a) vibration displacement and phase;

b) vibration spectra;

c) Bode plots;

d) shaft orbits;

e) bearing metal temperatures;

f) inlet oil pressures;

g) inlet and outlet oil temperatures.

8.3.5.4 At least 6 weeks prior to the first scheduled running test, the vendor shall submit to the purchaser detailed procedures for the mechanical running test and all specified running optional tests including acceptance criteria.

8.3.5.5 For units with oil seals, no individual shaft end seal shall have a leakage rate greater than 70 % of the total expected leakage from all shaft seals in a single machine.

8.3.5.6 All joints and connections shall be checked for leaks, and any leaks be corrected.

8.3.5.7 All warning, protective, and control devices used during the test shall be checked and adjusted as required.

8.3.5.8 All instrumentation used for the tests shall have valid calibration at the time of the test.

8.3.5.9 Entrance of oil into the flow path or across the separation seal during the mechanical running test is prohibited.

NOTE Typically buffer gas or other facilities are provided to accomplish this.

8.3.5.10 During the mechanical running test, the requirements of 8.3.5.10.1 through 8.3.5.10.6 shall be met.

8.3.5.10.1 The operation of all shop/vendor equipment and test instrumentation used during the test shall not influence test measurements or purchased equipment behavior.

8.3.5.10.2 The measured unfiltered radial vibration shall not exceed the limits of 6.8.9.1 in the operating speed range and be recorded throughout the test.

8.3.5.10.2.1 The measured unfiltered radial vibration shall not exceed the limits specified in 6.8.9.2 during excursions above N_{mc} to trip speed.

8.3.5.10.3 Axial vibration throughout the test shall meet the following requirements.

NOTE This is recognized as an initial attempt to limit the amount of axial vibration and its effects on dry gas seals. Purchaser and vendor can discuss the applicability of these requirements to their project.

8.3.5.10.3.1 The overall unfiltered axial vibration shall not exceed 15 microns (0.6 mil) p-p for all operating conditions.

NOTE For the purposes of this paragraph, vibration is periodic motion with a frequency greater than 0.5 Hz.

8.3.5.10.3.2 Slow roll vector subtraction of axial runout, as indicated during slow roll measurement at test, up to the limit specified in 6.6.1.3 can be applied to the value in 8.3.5.10.3.1.

8.3.5.10.4 Synchronous vibration amplitude and phase angle vs speed during deceleration shall be plotted before and after the 4-hour run.

8.3.5.10.4.1 Both the synchronous (one per revolution) and overall vibration levels shall be plotted.

8.3.5.10.4.2 The speed range covered by these plots shall be from trip speed to slow roll.

8.3.5.10.4.3 [●] If specified, these data shall also be furnished in polar form.

8.3.5.10.5 [●] If specified, all real-time vibration data as agreed by the purchaser and vendor shall be recorded and an electronic copy provided to the purchaser.

8.3.5.10.6 The following seal flow data shall be taken during the compressor mechanical running test.

a) For compressors with oil seals, inner oil leakage shall be measured at each seal.

b) For single dry gas seals, flow in the primary vent line shall be measured.

c) For tandem dry gas seals, flow in the primary vent line from each seal shall be measured.

d) For double dry gas seals, the total flow to each seal shall be measured.

e) Separation gas flow rate shall be monitored for each dry gas seal. Upon completion of the test any evidence of oil inboard of the separation seals is cause for rejection.

NOTE Flow in the vents of single or tandem seals can include buffer or separation gas, in addition to seal leakage.

8.3.5.10.7 Lube-oil and seal-oil inlet pressures and temperatures shall be varied through the operating range including trip values permitted in the compressor operating manual.

a) This shall be done during the 4-hour test.

b) The combination of pressure and temperature variations during the test will be agreed.

c) Lube-oil and seal-oil operating conditions shall be held until bearing temperatures have stabilized within 2 °F (1 °C) over 10 minutes.

d) Vibration and bearing temperature limits outside the operating range shall be agreed.

8.3.5.10.8 If the lube oil specified is not available, the test may be conducted using shop lube oil conditioned to a viscosity equivalent to that of the specified oil at site operating conditions.

8.3.5.10.9 Axial position and axial and radial vibration shall be monitored and recorded during the mechanical test.

8.3.5.10.10 All test data shall be supplied for the mechanical test whether successful or not.

8.3.5.11 The requirements of 8.3.5.11.1 through 8.3.5.11.4 shall be met after the mechanical running test is completed.

8.3.5.11.1 All hydrodynamic bearings shall be removed, inspected, and reassembled after the mechanical running test is completed.

8.3.5.11.2 If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test shall not be acceptable.

8.3.5.11.2.1 The final shop tests shall be run after these replacements or corrections are made.

8.3.5.11.2.2 A mechanical retest is not required when the compressor case is required to be dismantled to comply with the requirements of 8.3.5.11.1.

8.3.5.11.3 If minor scuffs and scratches occur on bearings, a cosmetic repair of these parts is not a cause for rerunning the test.

8.3.5.11.4 For liquid film seals, minor scratches due to dirt particles that do not dimensionally change nor affect functionality of the part are not a cause for rerunning the test.

8.3.5.12 [●] If specified, shaft end seals shall be removed for inspection following a successful running test.

NOTE Inspection of cartridge seals can require that the seal be returned to the seal manufacturer's facility.

8.3.6 Assembled Machine Gas Leakage Test

For assembled gas leak testing, refer to Parts 2, 3, or 4, as applicable.

8.3.7 Optional Tests

NOTE Additional optional tests are covered in Parts 2, 3, or 4, as applicable.

8.3.7.1 [●] Performance Test

If specified, a performance test shall be performed.

NOTE Performance testing requirements are covered in Parts 2, 3, or 4, as applicable.

8.3.7.2 [●] Field Performance Testing

8.3.7.2.1 The purchaser shall advise the vendor of any plans to verify compressor performance by site testing of the installed compressor train.

8.3.7.2.1.1 The testing shall be conducted with the compressor in as new condition and gas conditions conforming to the specified as nearly as practical.

8.3.7.2.1.2 Testing shall be in accordance with an agreed performance test code.

NOTE 1 As a guide, on-site testing can be conducted in accordance with ASME PTC 10 or ISO 5389.

NOTE 2 There is no expander-compressor test code. Field performance testing of expander-compressors will be as agreed.

8.3.7.2.2 Testing tolerances shall be jointly determined and applied to test results.

8.3.7.3 Helium Test After Hydrostatic Test

8.3.7.3.1 [●] If specified, the compressor casing shall be tested for gas leakage with helium at the MAWP.

8.3.7.3.2 The test shall be conducted with the casing submerged in water.

8.3.7.3.3 The water shall be at a higher temperature than the nil-ductility transition temperature for the material of which the part is made.

8.3.7.3.4 The MAWP shall be maintained for a minimum of 30 minutes, with no bubbles permitted. As an alternative, a nonsubmerged soap-bubble test may be performed.

8.3.7.3.5 This test is done after hydrostatic test.

8.3.7.4 [●] Sound-level Test

If specified, the sound-level test shall be performed in accordance with ISO 3744 or other purchaser standards or requirements.

NOTE This test cannot reflect field sound levels due to shop test environment.

8.3.7.5 Auxiliary-equipment Test

8.3.7.5.1 [●] If specified, auxiliary equipment such as oil systems and control systems shall be tested in the vendor's shop.

8.3.7.5.2 Details of the auxiliary-equipment tests shall be developed jointly by the purchaser and the vendor.

8.3.7.6 Post-test Inspection of Compressor Internals

8.3.7.6.1 [●] If specified, the compressor shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running test.

8.3.7.6.2 The assembled machine gas leakage test shall be performed after the post-test inspection.

NOTE The merits of post-test inspection of compressor internals can be evaluated against the benefits of shipping a unit with proven mechanical assembly.

8.3.7.7 Full-load/Full-pressure/Full-speed Test

8.3.7.7.1 [●] If specified, a full-load/full-pressure/full-speed (FLFPS) test shall be performed.

8.3.7.7.2 The details of the FLFPS test shall be developed jointly by the purchaser and the vendor.

8.3.7.7.3 This test may be substituted for the mechanical running test.

NOTE Typical compressor FLFPS tests are discussed in Annex G.

8.3.7.8 [●] Post-test Inspection of the Hydraulic Coupling Fit

If specified, after the running tests, hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub has not moved on the shaft during the tests.

8.3.7.9 [●] Spare-parts Test

Spare parts such as rotors, gears, diaphragms, bearings, and seals shall be tested as specified.

8.4 Preparation for Shipment

8.4.1 [●] Equipment shall be prepared for the type of shipment specified, including blocking of the rotor when necessary.

8.4.1.1 Blocked rotors shall be identified by means of corrosion-resistant tags attached with stainless steel wire.

8.4.1.2 The preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals.

8.4.1.3 If storage for a longer period is contemplated, the purchaser should consult with the vendor regarding the recommended procedures for the equipment.

8.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

NOTE Refer to API 686, Chapter 3.

8.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser.

8.4.3.1 The preparation shall include that specified in 8.4.3.1 through 8.4.3.15 (see Annex D of Parts 2, 3, and 4).

8.4.3.1.1 Except for machined surfaces, all exterior surfaces that may corrode during shipment, storage, or in service shall be given at least one coat of the manufacturer's standard paint.

8.4.3.1.2 The paint shall not contain lead or chromates.

NOTE Austenitic stainless steels are typically not painted.

8.4.3.2 Exterior machined surfaces except for corrosion-resistant material shall be coated with a rust preventive.

8.4.3.3 The interior of the equipment shall be clean and free from scale, welding spatter, and foreign objects.

8.4.3.4 The selection and application of preservatives or rust preventives shall be agreed.

8.4.3.5 Internal surfaces of bearing housings and carbon steel oil systems' components shall be coated with an oil-soluble rust preventive that is compatible with the lubricating oil.

8.4.3.6 Flanged openings shall be provided with metal closures at least 5 mm (0.1875 in.) thick with elastomer gaskets and at least four full-diameter bolts.

8.4.3.6.1 For studded openings, all nuts needed for the intended service shall be used to secure closures.

8.4.3.6.2 Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.

8.4.3.7 Threaded openings shall be provided with steel caps or round-head steel plugs. In no case shall nonmetallic (such as plastic) caps or plugs be used.

NOTE These are shipping plugs; permanent plugs are covered in 6.4.4.5.

8.4.3.8 Openings that have been beveled for welding shall be provided with closures designed to prevent entrance of foreign materials and damage to the bevel.

8.4.3.9 Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package.

8.4.3.10 The recommended lifting arrangement shall be described in the installation manual.

8.4.3.11 The equipment shall be identified with item and serial numbers.

8.4.3.11.1 Material shipped separately shall be identified with securely affixed, stainless steel tags indicating the item and serial number of the equipment for which it is intended.

8.4.3.11.2 Crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

8.4.3.12 A spare rotor, if purchased, shall be prepared for unheated indoor storage for a period of at least 12 years.

8.4.3.12.1 It shall be treated with a rust preventive and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor.

8.4.3.12.2 The rotor shall be crated.

8.4.3.12.3 [●] If specified, spare rotors shall be shipped in a container capable of nitrogen pressurization and suitable for long-term horizontal storage.

8.4.3.12.4 [●] If specified, the container shall be suitable for vertical storage.

8.4.3.12.4.1 The rotor shall be supported from its coupling end with a fixture designed to support a minimum of 1.5 times its weight without damaging the shaft.

8.4.3.12.4.2 Instructions on the use of the fixture shall be included in the installation, operation, and maintenance manuals.

8.4.3.12.5 Rotors shall have rust preventative coatings.

NOTE Relying on nitrogen for long-term storage protection requires that the owner provide a constantly available nitrogen source. This can also require outdoor storage due to hazards associated with leaking nitrogen in an enclosed area.

8.4.3.13 A suitable resilient material 3 mm (0.125 in.) thick [not tetrafluoroethylene or PTFE] shall be used between the rotor and the cradle at the support areas.

8.4.3.13.1 The rotor shall not be supported on journals.

8.4.3.13.2 The probe target areas shall be identified and protected.

NOTE Tetrafluoroethylene and PTFE are not recommended as cradle support liners since they could flow and impregnate into the surface.

8.4.3.14 [●] If specified, the fit-up and assembly of machine mounted piping and heat exchangers shall be completed in the vendor’s shop prior to shipment.

8.4.3.15 Exposed shafts and shaft couplings shall be wrapped with waterproof, moldable waxed cloth or volatile-corrosion inhibitor paper.

8.4.3.15.1 The seams shall be sealed with oil-proof adhesive tape.

8.4.3.15.2 The shaft end shall be protected against incidental mechanical damage.

8.4.4 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.

8.4.5 Service and connection designations shall be indicated.

8.4.6 Connections on auxiliary piping removed for shipment shall be match marked for ease of reassembly.

8.4.7 One copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

8.4.8 Wood used in export shipping shall comply with the requirements of ISPM 15.

9 Vendor's Data

9.1 The purchaser may specify the content of proposals, meeting frequency, and vendor data content/format identified in Annex I. Annex I provides a general outline of information that potentially may be requested by the purchaser.

9.2 [●] If specified, the information detailed in Annex I shall be provided.

Annex A
(normative)

Procedure for the Verification of Residual Unbalance

A.1 General

This annex describes a procedure to verify residual unbalance in rotors by determining the calibration accuracy of the balancing equipment. Balancing machines may be configured to display the amount of rotor unbalance; however, the calibration can be in error. To determine the actual residual unbalance, a known amount of unbalance should be added using an appropriate procedure.

A.2 Residual Unbalance

Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Residual unbalance shall be expressed in g-mm (g-in.).

A.3 Maximum Allowable Residual Unbalance

A.3.1 The maximum allowable residual unbalance, per plane, shall be calculated in accordance with Equation (A.1).

A.3.2 The static weight on each journal shall be determined by rotordynamic calculations. If the static loadings cannot be obtained from rotordynamic calculations then the method by which the journal weight was determined shall be identified. It should NOT 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 (even negative on overhung rotors).

A.4 Residual Unbalance Check

A.4.1 General

A.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. Record and plot the indicated residual unbalance heavy spot of both planes on the Residual Unbalance Worksheet (one for each plane).

NOTE Due to the possibility of machine calibration errors, the residual unbalance check can be performed prior to final correction of the unbalance, typically after the placement of temporary weights.

A.4.1.2 To check the residual unbalance, a known trial weight, equal to the multiplier from Table A.1 times the maximum allowable unbalance from Equation (A.1), is attached to the rotor at the same angular location as the indicated heavy spot. The check is run at each balance machine readout plane, and the readings in each plane are tabulated. This run is then repeated with the weight placed 180° opposite of the heavy spot at the same radius. The check is run at each balance machine readout plane, and the readings in each plane are tabulated.

Table A.1—Trial Weight Multiplier vs N_{mc}

Maximum Continuous Speed of Part/Assembly	Trial Weight Multiplier
$N_{mc} \leq 7500$ rpm	1.5
$7500 < N_{mc} \leq 12{,}500$ rpm	2.0
$N_{mc} > 12{,}500$ rpm	2.5

A.4.2 Procedure

A.4.2.1 Select a trial weight and radius that will be equivalent to the trial weight multiplier times the maximum allowable residual unbalance as defined by Equation (A.1).

NOTE If U_r is 488.4 g-mm (19.2 g-in.), for a rotor with $N_{mc} \leq 7500$ rpm, the trial weight magnitude should equal 732.6 g-mm (28.8 g-in.).

In g-mm units:

$$U_r = 6350 \frac{W}{N_{mc}} \quad \text{(for } N_{mc} < 25{,}000 \text{ rpm)} \tag{A.1a}$$

$$U_r = \frac{W}{3.937} \quad \text{(for } N_{mc} \geq 25{,}000 \text{ rpm)}$$

In g-in. units:

$$U_r = 113.4 \frac{W}{N_{mc}} \quad \text{(for } N_{mc} < 25{,}000 \text{ rpm)} \tag{A.1b}$$

$$U_r = \frac{W}{220.46} \quad \text{(for } N_{mc} \geq 25{,}000 \text{ rpm)}$$

A.4.2.2 At the heavy spot, add the first trial weight at the selected radius in A.4.2.1 to the first balance readout plane. Trial weight magnitude is a linear function with radial location. Every effort should be made to place the weight accurately, both radially and circumferentially.

A.4.2.3 Verify that the balancing machine's readings are stable without faulty sensors or displays.

NOTE When the trial weight is added to the last known heavy spot, the first meter reading can easily exceed the balance tolerance in that plane. 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).

A.4.2.4 Remove the trial weight and rotate the trial weight to the second position (i.e. 180° from the initial trial weight position). All verification shall be performed using only one sensitivity range on the balance machine.

A.4.2.5 Record and plot the balancing machine unbalance amplitude and phase readout (heavy spot) on the Residual Unbalance Worksheet for the readout plane in question. If the indicated unbalance phase angle for the residual unbalance (see A.4.1.1) differs by more than 10° from the first trial weight phase angle or the 2nd trial weight phase angle plus 180°, then the angular location of the trial weight should be adjusted to lessen the difference. Once the phase angle difference is less than 10°, the actual amount of residual unbalance (refer to worksheets, Figure A.2 and Figure A.3) can be calculated.

A.4.2.5.1 The difference in magnitudes of each trial weight run relative to the indicated unbalance should be within 20 %.

A.4.2.5.2 If this is exceeded, weight placement and magnitude should be reviewed. A larger trial weight can be used with the value entered into the “User Selected Trial Weight”; otherwise, this value should be zero.

NOTE 1 Not meeting this tolerance will generate errors in the calculated residual unbalance or indicate a problem with the balance machine.

NOTE 2 In Figure A.3, a larger trial weight was needed to enable the 2nd reading to be 180° different than the indicated reading (basically cross over the center of the plot.) The larger trial weight (9 g) was inputted into the “User Selected Trial Weight” cell. This value of the trial weight “TW” is then used to calculate the “Actual Residual Unbalance.” For this example, the machine was determined to be reading $^1/_2$ of the actual unbalance.

A.4.2.6 Repeat the steps described in A.4.2.1 through A.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 when calculating the actual residual unbalance, the rotor shall be balanced more precisely and checked for compliance using the calibration factors determined above.

A.4.2.7 For stack component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the rotor after the addition of the first rotor component and at the completion of balancing of the entire rotor, as a minimum.

NOTE 1 This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

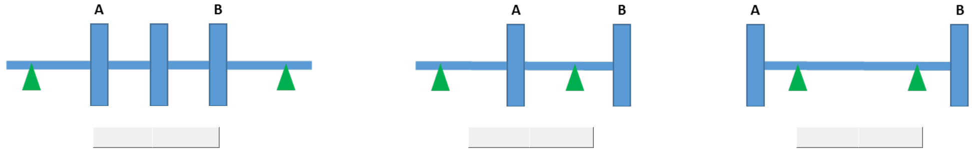
NOTE 2 For large multistage rotors, the journal reactions can be considerably different from the case of a partially stacked to a completely stacked rotor. Allowable unbalance tolerance is not varied as components are added and is based on total weight.

Customer:	
Job / Project Number:	
OEM Equipment S/N:	
Rotor Identification Number:	
Repair Purchase Order Number:	
Vendor Job Number:	
Correction Plane (A or B) - see sketch:	

Balancing Speed:			rpm		
Maximum Continuous Operating Speed:	**Nmcs**		rpm		
Static Journal Weight Closest to This Plane:	**W**		kg		lbm
W obtained from:		Rotordynamics			Specify if Other
Correction Radius - radius at which the readings are taken and trial weight will be placed:	**R**		mm		in

Balance Plane Description: End A End B

A B A B A B



Calculate the Maximum Allowable Residual Unbalance (Ur):

Nmcs ≤ 25000 rpm **Nmcs > 25000 rpm**

SI Units:

$$U_r = \frac{6350 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{3.937}$$

Ur ___ g-mm **Unbalance @ Balance Plane** ___ g

Customary Units: **(USC expressed in grams)**

$$U_r = \frac{113.4 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{220.46}$$

Ur ___ g-in **Unbalance @ Balance Plane** ___ g

Trial Weight Calculation:

$$TW = \frac{Um * U_r}{R}$$

Trial Weight Multiplier (Um): ___

Recommended Trial Weight: ___ g **User Selected Trial Weight:** 0.00 g

Record Indicated Residual Unbalance (A.4.1.1) and the Indicated Unbalance with Trial Weight (A.4.2.5)

Test Data

Unbalance Readings		Magnitude grams (g)		Phase Angle degrees (°)	
A: Residual Unbalance (IR)*					
B: Unbalance w/ 1st Trial Weight (Mx)*					
C: Unbalance w/ 2nd Trial Weight (Mn)*					
	Y = Mx - Mn	0.00	Angle Diff |B-A| <10	0.00	
	Z = Mx + Mn	0.00	Angle Diff |C-A| <10	180.00	
Trial Weight Effect	R1 = Mx - IR	0.00	R2 = Mn + IR	0.00	
	R1/R2		R2/R1		
Uniformity Of Trial Weight Placement & Effect:		*Caution: Potential Inaccuracies*			
Angle diff < 10 and Magnitude ratio [0.8 < (R1/R2 & R2/R1) < 1.2]		*If cautioned, increase weight or adjust weight placement angle*			
		Metric (g-mm)		Customary (g-in)	
Residual Unbalance Reading (IR*R)					
Actual Residual Unbalance (AR=R*TW*Y/Z)					
Within Specification (AR < Ur)					

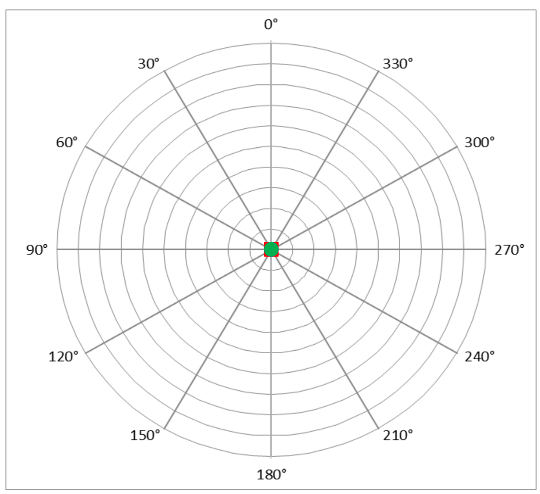
**** denotes indicated values***

Indicated Residual Unbalance

Indicated Unbalance w/ Trial Weight #1

Indicated Unbalance w/ Trial Weight #2

Indicates Input Required



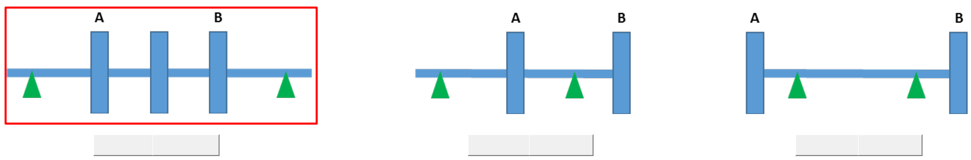
100% = #NUM! g

Figure A.1—Residual Unbalance Worksheet

Customer:	International Oil Company
Job / Project Number:	JN 2398-IRG-48
OEM Equipment S/N:	345-687
Rotor Identification Number:	C4784XL
Repair Purchase Order Number:	
Vendor Job Number:	12484-45985
Correction Plane (A or B) - see sketch:	Plane A

Balancing Speed:		400	rpm		
Maximum Continuous Operating Speed:	**Nmcs**	11000	rpm		
Static Journal Weight Closest to This Plane:	**W**	1300	kg		lbm
W obtained from:		Rotordynamics			Specify if Other
Correction Radius - radius at which the readings are taken and trial weight will be placed:	**R**	200	mm		in

Balance Plane Description: Thrust End A   Coupling End B



Calculate the Maximum Allowable Residual Unbalance (Ur):

Nmcs ≤ 25000 rpm **Nmcs > 25000 rpm**

SI Units:

$$U_r = \frac{6350 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{3.937}$$

Ur: 750.45 g-mm   **Unbalance @ Balance Plane:** 3.75 g

Customary Units: **(USC expressed in grams)**

$$U_r = \frac{113.4 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{220.46}$$

Ur: g-in   **Unbalance @ Balance Plane:** g

Trial Weight Calculation:

$$TW = \frac{Um * U_r}{R}$$

Trial Weight Multiplier (Um): 2

Recommended Trial Weight: 7.50 g   **User Selected Trial Weight:** 0.00 g

Record Indicated Residual Unbalance (A.4.1.1) and the Indicated Unbalance with Trial Weight (A.4.2.5)

Test Data

Unbalance Readings		**Magnitude grams (g)**		**Phase Angle degrees (°)**	
A: Residual Unbalance (IR)*		3.5		65	
B: Unbalance w/ 1st Trial Weight (Mx)*		10.7		62	
C: Unbalance w/ 2nd Trial Weight (Mn)*		4.2		247	
	Y = Mx - Mn	6.50	**Angle Diff |B-A| <10**	3.00	
	Z = Mx + Mn	14.90	**Angle Diff |C-A| <10**	2.00	
Trial Weight Effect	**R1 = Mx - IR**	7.20	**R2 = Mn + IR**	7.70	
	R1/R2	0.94	**R2/R1**	1.07	
Uniformity Of Trial Weight Placement & Effect:		**Acceptable**			
Angle diff < 10 and Magnitude ratio [0.8 < {R1/R2 & R2/R1} < 1.2]		*If cautioned, increase weight or adjust weight placement angle*			
		Metric (g-mm)		**Customary (g-in)**	
Residual Unbalance Reading (IR*R)		700.00			
Actual Residual Unbalance (AR=R*TW*Y/Z)		654.76			
Within Specification (AR < Ur)		YES			

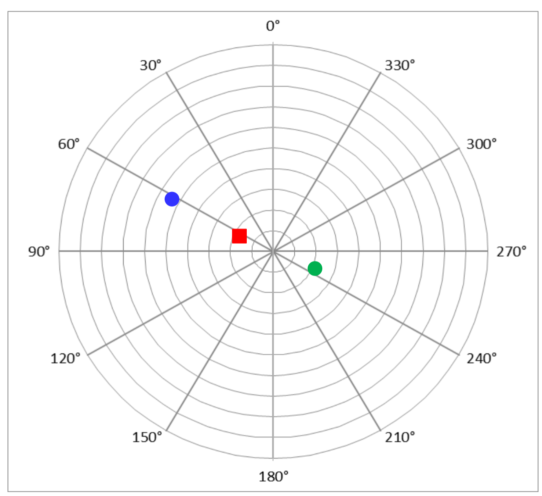
**** denotes indicated values***

Indicated Residual Unbalance

Indicated Unbalance w/ Trial Weight #1

Indicated Unbalance w/ Trial Weight #2

Indicates Input Required

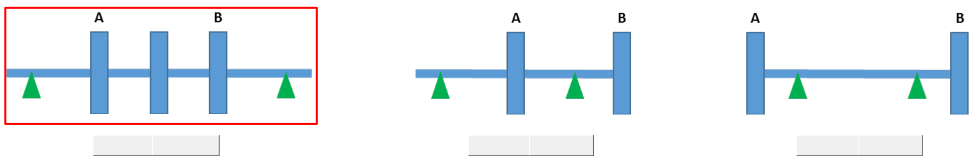


100% = 20 g

Figure A.2—Sample Residual Unbalance Worksheet for Left Plane (Metric)

Customer:		US Oil Company			
Job / Project Number:		JN 2398-IRG-48			
OEM Equipment S/N:		345-687			
Rotor Identification Number:		C4784XL			
Repair Purchase Order Number:					
Vendor Job Number:		12484-45985			
Correction Plane (A or B) - see sketch:		Plane B			
Balancing Speed:		400	rpm		
Maximum Continuous Operating Speed:	**Nmcs**	11000	rpm		
Static Journal Weight Closest to This Plane:	**W**		kg	2866	lbm
W obtained from:		Rotordynamics			Specify if Other
Correction Radius - radius at which the readings are taken and trial weight will be placed:	**R**		mm	8	in

Balance Plane Description: Thrust End A Coupling End B



Calculate the Maximum Allowable Residual Unbalance (Ur):

Nmcs ≤ 25000 rpm **Nmcs > 25000 rpm**

SI Units:

$$U_r = \frac{6350 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{3.937}$$

Ur		**Unbalance @ Balance Plane**	
	g-mm		g

Customary Units: **(USC expressed in grams)**

$$U_r = \frac{113.4 * W}{N_{mcs}} \quad \text{or} \quad U_r = \frac{W}{220.46}$$

Ur		**Unbalance @ Balance Plane**	
29.55	g-in	3.69	g

Trial Weight Calculation:

$$TW = \frac{Um * U_r}{R}$$

Trial Weight Multiplier (Um): 2

Recommended Trial Weight:		**User Selected Trial Weight:**	
7.39	g	9.00	g

Record Indicated Residual Unbalance (A.4.1.1) and the Indicated Unbalance with Trial Weight (A.4.2.5)

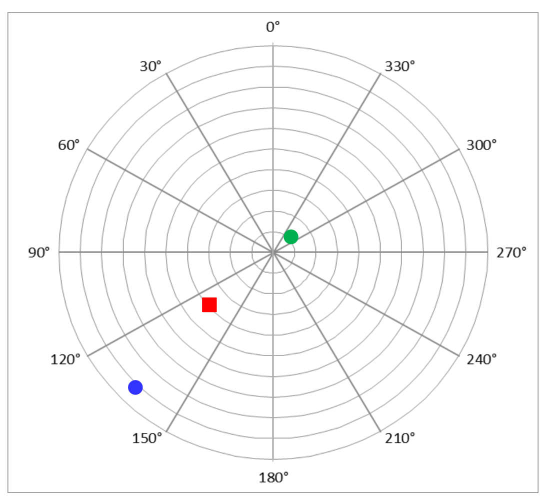
Test Data

Unbalance Readings		**Magnitude grams (g)**		**Phase Angle degrees (°)**	
A: Residual Unbalance (IR)*		3.5		130	
B: Unbalance w/ 1st Trial Weight (Mx)*		8.2		135	
C: Unbalance w/ 2nd Trial Weight (Mn)*		1		312	
	Y = Mx - Mn	7.20	**Angle Diff |B-A| <10**	5.00	
	Z = Mx + Mn	9.20	**Angle Diff |C-A| <10**	2.00	
Trial Weight Effect	**R1 = Mx - IR**	4.70	**R2 = Mn + IR**	4.50	
	R1/R2	1.04	**R2/R1**	0.96	
Uniformity Of Trial Weight Placement & Effect:		**Acceptable**			
Angle diff < 10 and Magnitude ratio [0.8 < {R1/R2 & R2/R1} < 1.2]		*If cautioned, increase weight or adjust weight placement angle*			
		Metric (g-mm)		**Customary (g-in)**	
Residual Unbalance Reading (IR*R)				28.00	
Actual Residual Unbalance (AR=R*TW*Y/Z)				56.35	
Within Specification (AR < Ur)				NO	

**** denotes indicated values***

- ■ Indicated Residual Unbalance
- ● Indicated Unbalance w/ Trial Weight #1
- ● Indicated Unbalance w/ Trial Weight #2

Indicates Input Required



100% = 9 g

Figure A.3—Sample Residual Unbalance Worksheet for Right Plane (USC)

Annex B
(normative)

Report Requirements for Lateral and Stability Analyses

B.1 Standard Lateral Analysis and Stability Report

a) Rotor model:

   1) sketch of rotor model;

   2) clear identification of bearing, shaft end and internal seals, probe, coupling, and disc (impellers, wheels, etc.) locations.

b) Oil film bearings and liquid-film seals data (if present):

   1) dynamic coefficients (plot or table) for minimum and maximum stiffness cases vs speed and power;

   2) in the stability analysis, the synchronous and/or nonsynchronous coefficients when used by manufacturer;

   3) identification of coordinate system including direction of rotation;

   4) bearing type, length, pad arc length, diameter, minimum and maximum clearance and corresponding preload range, offset, number of pads, and pivot type, materials (ball and socket if applicable) and geometry (i.e. for tilt pad bearings load on pad vs load between pad);

   5) bearing load and direction vs speed and power;

   6) oil film seal configuration, length, diameter, minimum and maximum clearance, seal eccentricity vs speed and pressure, clearance taper and seal geometry;

   7) oil properties and operating conditions:

      — oil viscosity (two temperature data if a nonstandard ISO Grade);

      — oil flow rate and/or inlet pressure;

      — inlet operating temperature range;

      — oil specific gravity;

      — seal operating conditions.

c) Bearing pedestal data:

   1) identify parameters vs frequency (mass, stiffness, and damping).

d) Gas annular seal data:

   1) coefficients for labyrinth seals, balance piston seal, and/or center bushing seal (both speed and frequency dependence);

   2) seal type (labyrinth, honeycomb, hole pattern, etc.);

   3) teeth on rotor, teeth on stator, or interlocking;

   4) seal minimum and maximum operating clearance and taper;

   5) presence of shunt holes and/or swirl brakes.

e) Squeeze film dampers:

1) dynamic coefficients for clearance range vs frequency;

2) steady-state static position and whirl eccentricity;

3) identification of coordinate system including direction of whirl;

4) damper type, length, diameter, minimum and maximum clearance, centering device, and end seal type;

5) stiffness values for end seals and centering device (when used);

6) cavitation model.

f) Other forces included in the analysis (machine dependent):

1) motor stator magnetic stiffness;

2) volute fluid dynamic forces;

3) gear mesh loads.

NOTE The vendor will typically state force magnitude and basis of calculation.

g) Analysis methods:

1) list computer codes used in the analysis with a brief description of the type of code, e.g. finite element, computational fluid dynamics (CFD), transfer matrix, etc.

h) Undamped critical speed map and mode shapes:

1) critical speed vs support stiffness;

2) curves of the support stiffness (i.e. K_{xx} and K_{yy} for minimum and maximum stiffness) where K_{xx} is horizontal stiffness and K_{yy} is vertical stiffness;

3) plot, as a minimum, the first four critical speeds with the stiffness axis extending from “free-free” to “rigid” support regions;

4) show the minimum allowable speed and N_{mc};

5) the map shall be displayed as shown in Figure B.1;

6) undamped mode shapes from the free-free, expected, and rigid support regions;

7) for machines that do not have similar support stiffness, the critical speed map shall indicate the specified reference bearing and its location; for each of the other bearing locations, the bearing stiffness ratio, relative to the specified reference bearing, shall be defined:

— the vendor can substitute mode shape plots for the undamped critical speed map and list the undamped critical speeds and the support stiffness for each of the identified modes.

i) Unbalance response predictions:

1) identification of the frequency of each critical speed in the range from 0 to 150 % of N_{mc};

2) frequency, phase, and amplitude (Bode plots) at the vibration probe locations in the range 0 to 150 % of N_{mc} resulting from the unbalances specified in 6.8.2.7 and 6.8.2.8:

— if the location of the vibration probes is outside the requirements of API 670, then the Bode plots shall be shown at the bearing centerline and probe;

— minimum allowable and N_{mc} shown;

— for min and max bearing stiffness cases;

— pedestal vibration amplitudes for flexible pedestals as defined in 6.8.2.4 d);

3) tabulation of critical speeds, AF, and actual and required separation margin;

4) axial location, amount, and phase of unbalance weights for each case;

5) scale factor (S_{cc}) or multiple of API residual unbalance;

6) plots of deflected rotor shape at critical speeds and N_{mc} for min and max bearing stiffness cases with the scaled unbalances using the scale factors in 6.8.2.11.

7) a table of the close clearance magnitudes and locations and maximum vibration levels verifying that 6.8.2.11.1 has been met.

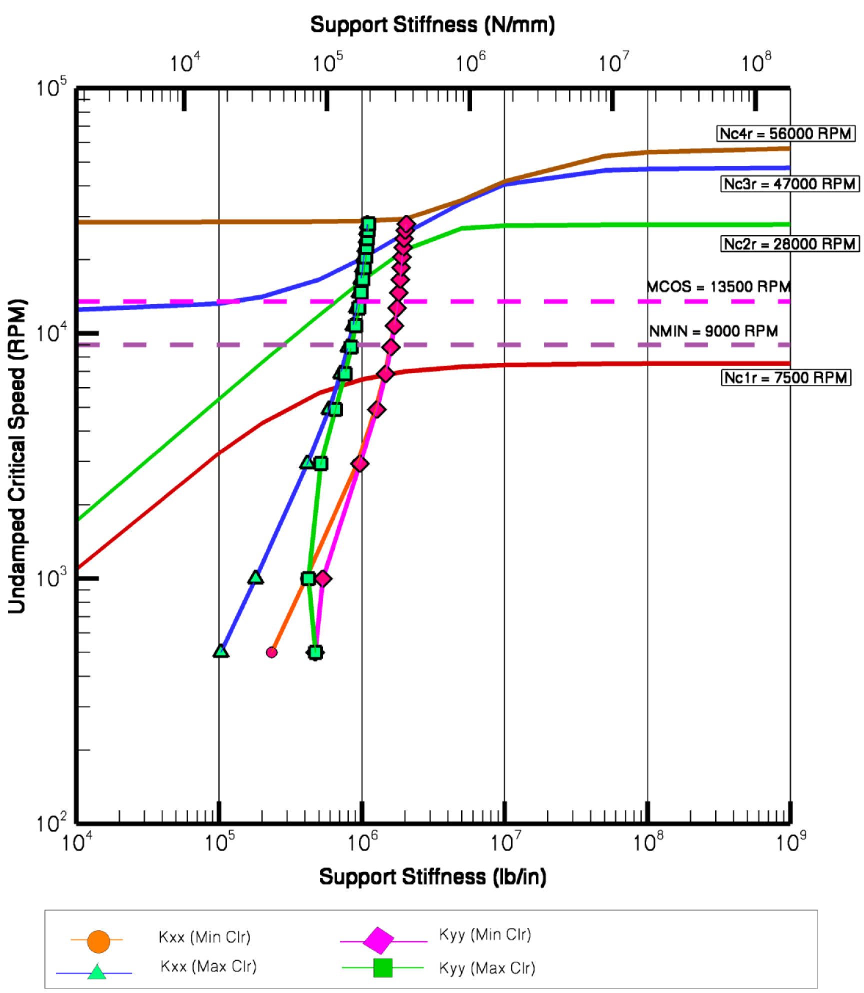


Figure B.1—Undamped Critical Speed Map

j) Stability analysis:

1) description of all assumptions used in the analysis;

2) description of all dynamic effects included in the analysis;

3) the calculated anticipated cross coupling, q_a (for each centrifugal impeller or axial stage), total anticipated cross coupling, Q_A, log dec and damped natural frequency at anticipated cross coupling, and Q_0/Q_A (defined in 6.8.4.7);

4) Figure B.2 plot of log dec vs cross coupled stiffness for min and max bearing stiffness (defined in 6.8.4.15);

5) value of log dec and frequency vs component addition for min and max bearing stiffness (defined in 6.8.4.14);

6) summary sheet that identifies compliance with API requirements.

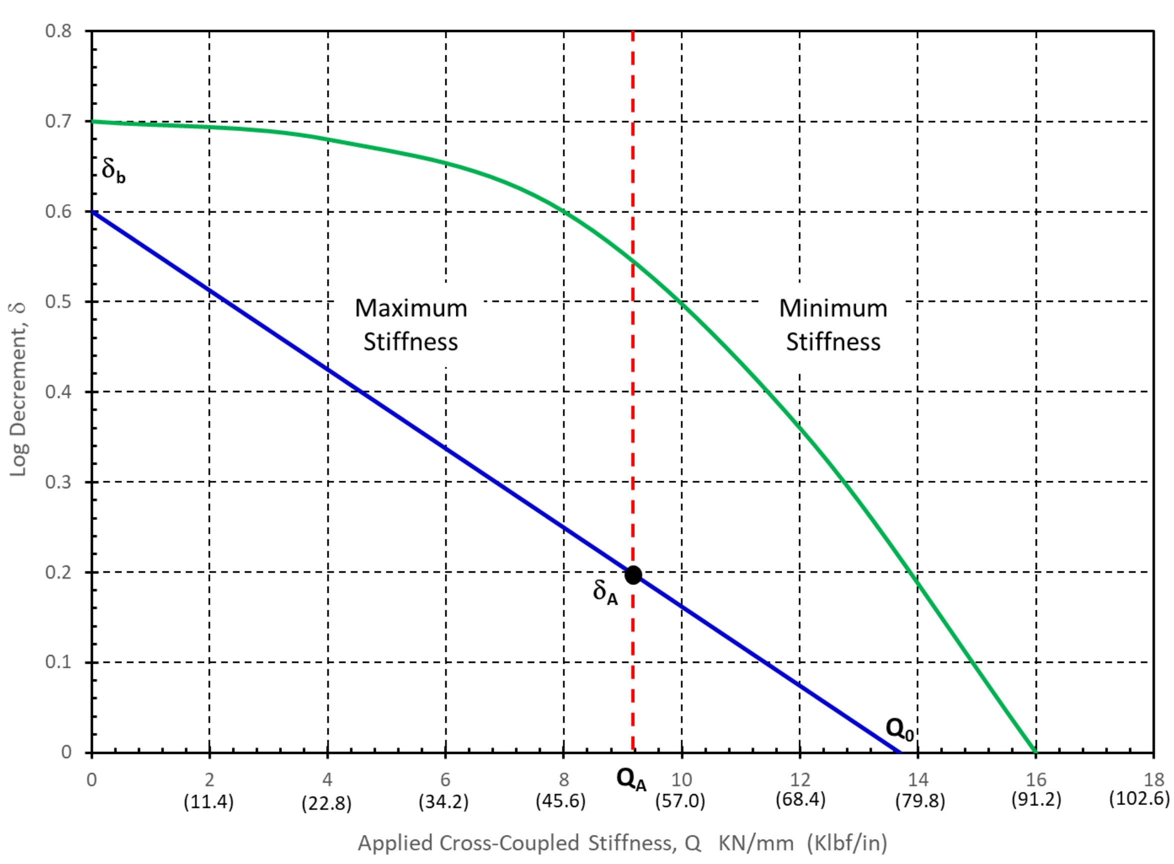


Figure B.2—Stability Sensitivity Plot

B.2 Data Required to Perform Independent Audits of Lateral and Stability Analysis

a) All of the requirements of B.1 shall be met. This requirement details additional data that shall be provided in conjunction with the Standard Lateral Analysis and Stability Report or as an addendum to it.

b) Rotor model:

   1) model tabulation to include rotor geometry (including delineation between stiffness and mass diameter);

   2) the weight, polar and transverse moments of inertia, attachment location and center of gravity of the impellers, balance piston, shaft end seals, coupling(s), and any other rotating components;

   3) shaft material properties (density and Young's Modulus);

   4) axial preloading due to tie bolts.

c) Bearing and liquid-film seal:

   1) data to permit independent calculation of bearing coefficients:

      — Table B.1, Figure B.3, and Figure B.4 indicate geometry required for tilt pad bearings;

      NOTE Similar dimensions are required for fixed pad bearings when used. API 684 can assist in the determination of the dimensions needed.

   2) seal dimensional data;

   3) the magnitude and direction of any loads (gears forces, volutes, etc.) other than gravity over the full operating range.

d) Internal seals (labyrinth, balance piston, wear rings, and center bushing):

   1) dimensional data;

   2) inlet swirl ratio;

   3) swirl brake type;

   4) clearance assumptions;

   5) shunt hole location;

   6) gas conditions and properties at operating speed;

   7) for damper seals, the gas conditions and properties from 0 to N_{mc} as agreed.

Table B.1—Tilt Pad Bearing Dimensions and Tolerances

Dimension	Nominal	Tolerance (+)	Tolerance (−)
Shaft diameter at journal ($2 \times R_j$)			
Pad machined diameter ($2 \times R_p$)			
Set bore ($2 \times R_b$)			
Pivot offset (α)			
Pad arc length (χ)			

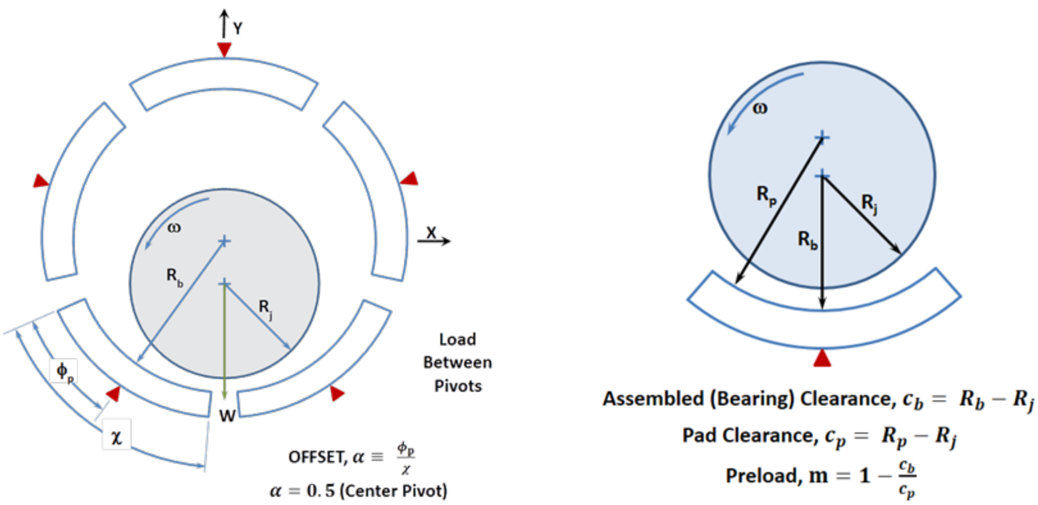


Figure B.3—Geometry Definitions for Tilt Pad Bearing

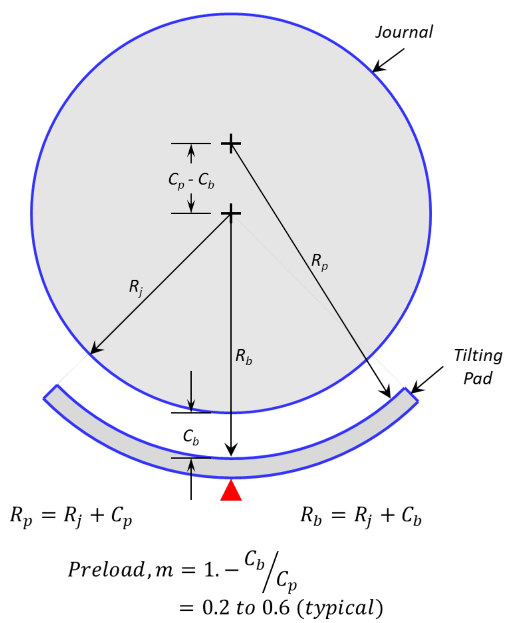


Figure B.4—Preloaded Pad

Annex C
(normative)

Requirements for Torsional Analysis Reports

(Report Requirements for Torsional Natural Frequency, Steady-state Torsional Response, and Transient Torsional Response Analyses)

C.1 Standard Torsional Natural Frequency Report (for Systems That Comply with Separation Margins)

a) Torsional model:

1) sketch of torsional system;
2) clear identification of individual rotors and their associated inertias and coupling locations;
3) shaft element length and diameters;
4) shaft material properties (material density, shear modulus of elasticity, and strength properties);
5) identify inertia magnitude and location;
6) identify what each lumped inertia represents;
7) identify inertia of each body and the total for the train.

NOTE Inertia and stiffness are expected to be actual values and not referenced to a particular shaft.

b) Coupling data:

1) stiffness and inertia, with a tolerance for the stiffness;
2) elastomeric type couplings; a torque vs stiffness based on elastomeric element hardness shall be provided;
3) description of shaft end model accounting for hub penetration.

c) Analysis methods:

1) list computer codes used in the analysis with a brief description of the type of code, e.g. finite element, Holzer, etc.

d) Torsional natural frequencies:

1) table of the torsional natural frequencies up to 2 times the highest rotor speed including separation margins.

e) Natural frequency mode shapes:

1) plots for all torsional natural frequencies that are less than or equal to 2 times the highest rotor speed.

f) Campbell diagram:

1) identify torsional natural frequencies;
2) identify operating speed range(s) with 10 % separation margin for train components;
3) identify torsional excitation frequencies.

NOTE A typical diagram is shown in Figure C.1.

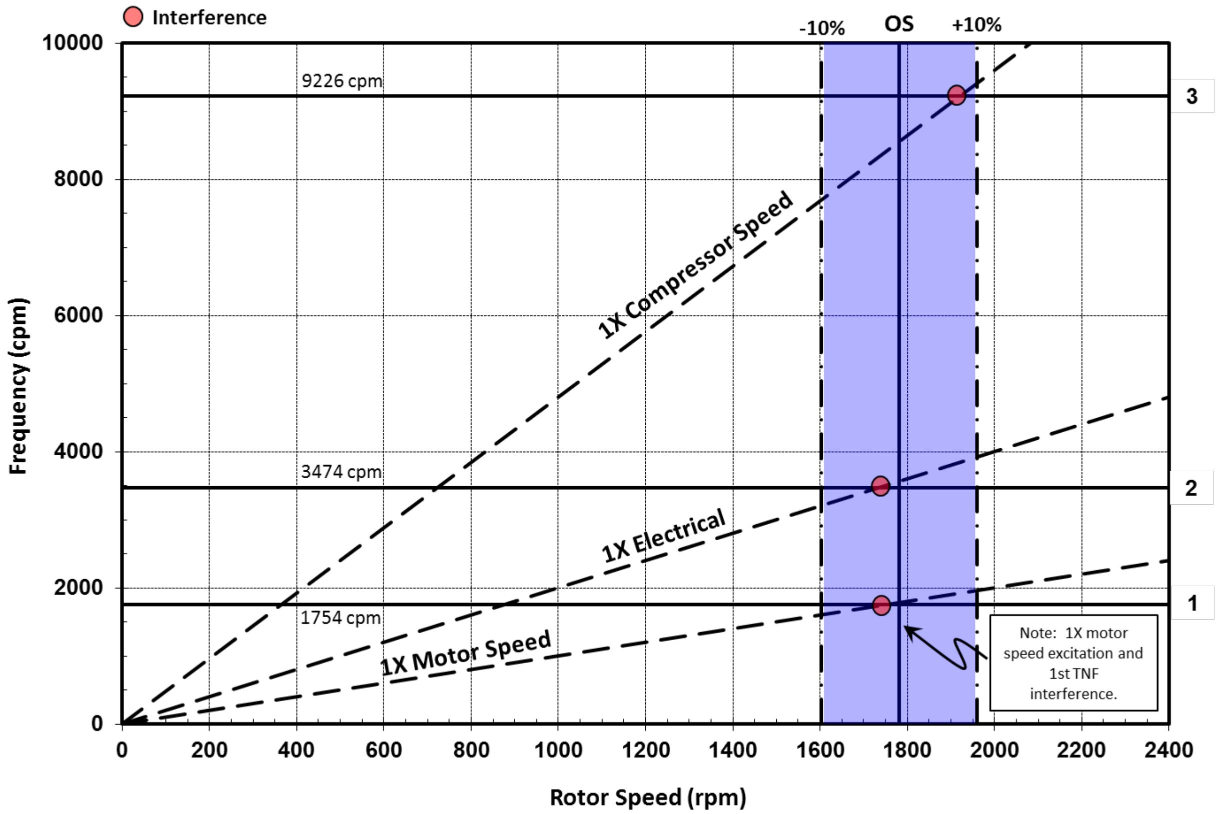


Figure C.1—Typical Campbell Diagram

C.2 Standard Torsional Natural Frequency Report [for Systems That Do Not Comply with Separation Margin(s)]

NOTE For adjustable frequency motor drives, refer to C.3.

All of the items in C.1 above are required in addition to the following.

a) A statement of the potential torsional excitation mechanism(s), its location, magnitude, and frequency. For systems that operate at variable speeds, the excitation mechanism shall be evaluated throughout the operating speed range.

b) Damping levels used in the analysis shall be stated.

c) The calculated peak torques for all couplings and gear mesh(s) shall be identified.

d) The calculated maximum shaft stress for each shaft shall be presented.

e) Shaft stress concentration factors applied shall be listed.

f) Statement of fatigue life acceptance criteria used and conformance.

C.3 Standard Torsional Natural Frequency Report for Adjustable Frequency Drives

All of the items in C.1 above are required [with the addition of identifying the AFD excitations on the Campbell diagram required in C.1 f)], and the following information shall be provided.

a) Train acceleration schedule.

b) The excitation associated with the AFD throughout the entire speed range shall be identified as a percentage of rated driver torque.

c) Damping levels and low- and high-cycle fatigue of shaft materials used shall be stated.

d) The calculated peak torques for all couplings and gear mesh(s) shall be identified.

e) The calculated maximum shaft stress for each shaft shall be presented.

f) Shaft stress concentration factors applied shall be listed.

g) Statement of fatigue life acceptance criteria used and conformance.

C.4 Standard Transient Torsional Analysis of Synchronous Motor Drives Report (In the Absence of an AFD)

The standard torsional natural frequency report associated with a conventional torsional natural frequency analysis shall be provided in accordance with C.1 and C.2 above, as appropriate. In addition, the following shall be provided.

a) The speed torque curve for the motor identifying the mean and alternating torque shall be plotted.

NOTE For a realistic transient analysis, the motor speed torque will reflect the expected starting voltage drop and voltage recovery.

b) A load speed torque curve of the driven equipment identifying the process conditions under which the equipment is required to start shall be included.

c) Damping levels and shaft material fatigue strength properties used shall be stated.

d) The calculated transient torque vs speed for couplings, gear mesh(s) and selected shaft sections shall be plotted. Calculated peak torques at the couplings and gear mesh shall be identified.

e) The calculated transient stress vs speed for selected shaft sections with high-cycle fatigue (endurance) and the low-cycle fatigue limits shall be identified.

f) Results of the damage accumulation calculations as a function of one start.

g) Predicted number of starts to failure for each shaft, coupling(s), and gear mesh.

C.5 Standard Transient Analysis of Electric Motor/Generator Short Circuit, Synchronization, and Breaker Reclosure Report

The standard torsional natural frequency report associated with a conventional torsional natural frequency analysis shall be provided in accordance with C.1 and C.2 above as appropriate. In addition, the following shall be provided.

a) The torque magnitude and frequency associated with the short circuit faults, synchronization, or breaker reclosure conditions shall be identified.

b) The analysis shall identify the calculated peak torques in all rotors and couplings. The shaft stress at each of the peak torque locations shall be calculated and evaluated using criteria suitable for either high-cycle or low-cycle fatigue.

c) Damping levels and shaft material fatigue strength properties used shall be stated.

d) The calculated transient torque vs time for couplings, gear mesh(s), and selected shaft sections shall be plotted. Calculated peak torques at the couplings and gear mesh shall be identified.

e) The transient stress vs time for selected shaft sections with low-cycle fatigue identified shall be plotted.

f) A summary shall be included stating that the shafting and gear mesh stress does not exceed low-cycle fatigue and that the coupling(s) do not exceed their peak torque rating.

g) For breaker reclosure, the acceptance criteria shall be stated.

Annex D
(normative)

Magnetic Bearings

D.1 General

This annex covers the additional minimum requirements and modifications for machines that have AMBs to the requirements presented in Part 1.

NOTE Magnetic bearings present unique requirements as opposed to hydrodynamic bearings. Additional requirements for magnetic bearings and superseding requirements applying to magnetic bearings from the hydrodynamic bearing requirements covered in this part of API 617 are as indicated.

D.2 Referenced Publications

For the purposes of this annex, the following normative references apply. The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be agreed by the purchaser and the vendor:

a) EN 55011, Group 1, Class A;

b) EN 61000-6-2;

c) ISO 14839-1;

d) ISO 14839-3.

D.3 Terms, Definitions, and Abbreviations

For the purposes of this document, the following terms, definitions, and abbreviations apply.

D.3.1
active magnetic bearing
AMB
To support a rotor, without mechanical contact, using only attractive magnetic forces based upon servo feedback technology that normally consists of sensors, electromagnets, power amplifiers, power supplies, and controllers.

NOTE Adapted from ISO 14839-1.

D.3.2
actuator
Portion of the AMB system that applies a force to the rotor by converting a current into a magnetic force.

D.3.3
AMB control system
Device that detects and processes the sensor signal and transfers it to the power amplifier in order to regulate the magnetic attractive force to levitate the rotor.

NOTE Adapted from ISO 14839-1.

D.3.4
auxiliary bearing
Separate bearing system that supports the shaft when the shaft is not levitated by the AMB system or the AMB is overloaded. The auxiliary bearing is inactive under normal AMB operation. This bearing system may have a very limited life and be considered a consumable machine protection system.

Also known as a “touchdown,” “catcher,” “backup,” and/or “coastdown” bearing.

D.3.5
bearing axis
Location and specific direction in which the force acts or a rotor displacement is measured.

NOTE For horizontal axis machines, the radial bearing axes are typically at ±45° from vertical.

D.3.6
closed loop transfer function
Ratio of output response to input excitation signal for an actively controlled system, including the effects of the feedback loop.

NOTE Refer to ISO 14839-3 for a more precise mathematical definition.

D.3.7
compensator
AMB controller, including any input and/or output transformations. The inputs to the compensator are the sensor outputs. The outputs of the compensator are the current or force commands.

D.3.8
controlled plant
Power amplifier(s), actuator(s), rotor/housing dynamics, sensor(s), digital controller, sampling and computational delays. This term is used refer to a single axis or multiple axes jointly.

D.3.9
delevitation
Loss of sensation or AMB control of rotor position.

D.3.10
free-free map
Plot of natural frequencies for the complete rotating assembly including all components (mechanical bearings, seals, etc.) as a function of operating speed. Analysis is performed at zero support stiffness.

D.3.11
landing surface or landing sleeve
Surface on the rotating assembly that is meant to contact the auxiliary bearing surface when the rotor comes into contact with it.

D.3.12
levitation
Activating the AMB system to provide currents to the bearing such that the rotor is suspended within the magnetic bearing; can be used to refer to a single axis or the entire AMB system.

D.3.13
local electronics
Any electrical components required by the magnetic bearing system that are not included in the control system cabinet and are thus located on or near the machine skid.

D.3.14
no collocation
Refers to the usual arrangement where the bearing actuator is not located in the same axial location as the corresponding position sensor.

D.3.15
sensitivity function
Sensitivity is the ratio of response to excitation. Excitation is injected (added) to the close loop at the controlled plant input as shown in Figure D.1. Response is the sum of the injection signal and the sensor output.

NOTE Refer to ISO 14839-3 for a more precise mathematical definition.

D.3.16
synchronous response control
Any control scheme that is phase and frequency locked to rotor rotation and has the objective of minimizing the synchronous (and/or integer harmonic) component of the combination of rotor response and bearing force.

D.3.17
transfer function
Mathematical relationship of the output to input of a control system, considering gain and phase over a relevant frequency bandwidth.

D.4 General

D.4.1 Dimensions and Units

The dimensional and unit requirements of 4.1 shall apply.

D.4.2 Statutory Requirements

The statutory requirements of 5.1 shall apply.

D.4.3 No Specific Requirement

D.4.4 Basic Design

AMB systems shall be in accordance with 6.1 unless otherwise agreed and with the additional requirements as follows.

D.4.4.1 Vendor shall supply bearings suitable for the intended operating environment including any liquids that are expected to enter the bearing system during normal operation and shutdown periods.

D.4.4.1.1 For turboexpander applications, purchaser shall notify vendor of intended liquid injection (MEG, methanol, etc.) into process streams and flag for awareness potentially affected streams, i.e. seal gas sources downstream from injected liquid recovery sites.

D.4.4.2 All components shall be suitable for operation, both during shop tuning and testing and under field conditions.

D.4.4.3 All leads (power, sensor, speed, and temperature) shall be identified at both ends. Identification shall be durable in the intended environment and shall be able to withstand handling associated with installation and removal.

D.4.4.4 For expander-compressors covered in Part 4, the design shall be such that all the magnetic bearing stationary components (excluding wiring) inside the casing can be removed and replaced with the cartridge as a single unit.

NOTE For radial bearings larger than 240 mm, it can be preferable to split the radial and thrust bearings into separate cartridges for ease of handling due to close clearances and large masses.

D.4.4.5 [●] The purchaser shall specify the power and control wiring seal requirements within casing and AMB panel.

NOTE This can include dual seals and/or additional pressure sensor in between seals.

D.4.5 Materials

D.4.5.1 AMB systems shall be in accordance with 6.2 unless otherwise agreed and with the additional requirements as follows.

D.4.5.2 Electrical insulation of stator windings shall be Class H (180 °C) as a minimum. Overall bearing assembly shall be rated to Class F (155 °C) as a minimum.

D.4.6 Casings

AMB systems shall be in accordance with 6.3 as applicable, unless otherwise agreed.

D.4.7 Rotating Elements

AMB systems shall be in accordance with 6.6 as applicable, unless otherwise agreed, and with the additional requirements as follows.

D.4.7.1 The rotor shaft sensing areas observed by radial and axial shaft displacement sensors shall be as required to meet the requirements of the AMB sensor system. This requirement shall replace the relevant portions of 6.6.1.2, 6.6.1.3, and 6.6.1.4.

D.4.7.2 Sufficient area shall be provided on the AMB rotor segment to turn the assembled shaft assembly on a balancing machine. The measured runout of the AMB sensor when the shaft is supported on the surface used for balancing shall not exceed 5 μm (0.0002 in.).

D.4.7.3 Rotor landing surfaces shall be either repairable or replaceable, without causing replacement of the entire rotor system.

D.4.8 Dynamics

D.4.8.1 General

AMB systems shall be in accordance with 6.8 as applicable and with the additional and modified requirements as follows.

D.4.8.1.1 In the design of rotor-bearing and AMB systems, consideration shall also be given to AMB sensor runout.

D.4.8.1.2 Analysis requirements specified in D.4.8.2.1 through D.4.8.7 shall be reported per D.4.8.1.2.1 and D.9.

D.4.8.1.2.1 [●] If specified, the reporting requirements identified as required for independent audit of the results shall be provided.

D.4.8.2 Lateral Analysis

D.4.8.2.1 A free-free map shall be generated over the range of 0 to 150 % of N_{mc} in speed and shall include, as a minimum, all modes below 300 % of N_{mc} in frequency.

D.4.8.2.2 The rotordynamics analysis shall also include:

a) any effects of sensor-actuator no collocation;

b) the complete transfer functions from relative displacements at all AMB journal and sensor surfaces to all AMB forces;

c) any negative stiffness effects.

D.4.8.2.3 The rotordynamic analyses shall be conducted with synchronous response control (e.g. unbalance force rejection control) disabled, if provided.

D.4.8.2.4 The requirements specified in 6.8.2.10 shall be replaced with the following.

The calculated unbalanced peak-to-peak response at each vibration probe, for each unbalance amount and case as specified in 6.8.2.7, shall not exceed the smaller of Equation (D.1) or 0.3 times the minimum diametral close clearance (typically the auxiliary bearing), over the range of N_{ma} to N_{mc} as shown in Figure 3.

In SI units:

$$A_{vl} = 3\left(25.4\sqrt{\frac{12{,}000}{N_{mc}}}\right) \tag{D.1a}$$

In USC units:

$$A_{vl} = 3\left(\sqrt{\frac{12{,}000}{N_{mc}}}\right) \tag{D.1b}$$

where

A_{vl} is the mechanical test vibration limit, µm (mil);

N_{mc} is the maximum continuous speed (rpm).

D.4.8.2.5 The predicted dynamic forces for each analysis required in 6.8.2.7 and 6.8.2.11 shall be less than the AMB vendor-specified allowable dynamic force capacity envelope vs frequency for the given machine. This force capacity envelope shall include an agreed factor of safety relative to the maximum rated dynamic force that shall be greater than or equal to 1.5.

D.4.8.2.6 If the analysis indicates that the force limit requirements cannot be met, and the purchaser and the vendor have agreed that all practical design and retuning efforts have been exhausted, then acceptable dynamic force levels shall be agreed.

D.4.8.3 Closed Loop Transfer Function Model Verification Test

D.4.8.3.1 [●] If specified, the unbalance rotor response verification test specified in 6.8.3 shall be replaced with the transfer function-based procedure described in D.4.8.3.2 through D.4.8.3.10 for the radial bearing axes. The additional unbalance cases specified in 6.8.2.8 shall not be performed.

D.4.8.3.1.1 [●] If specified, both the unbalance rotor response verification test specified in 6.8.3 and the transfer function-based procedure described in D.4.8.3.2 through D.4.8.3.10 shall be performed for the radial bearing axes.

NOTE The unbalance-based procedure specified in 6.8.3 can require disassembly of the machine for some AMB supported machinery.

D.4.8.3.1.2 The transfer function-based procedure described in D.4.8.3.2 through D.4.8.3.10 shall be performed for the axial axis.

D.4.8.3.2 All analytical closed loop transfer functions shall be calculated.

D.4.8.3.3 Transfer function measurements shall be performed as part of the mechanical running test and the results shall be used to verify the analytical model.

D.4.8.3.4 Closed loop transfer function measurements shall be made as described in D.4.8.3.6 through D.4.8.3.6.4 at 0 rpm.

D.4.8.3.5 [●] If specified, a second measurement as described in D.4.8.3.6 through D.4.8.3.6.4 shall be made at an additional agreed speed(s).

NOTE Measurements at higher speeds, in some cases, will not be suitable for validation purposes due to the presence of immeasurable forces from unbalance, aerodynamic forces, etc.

D.4.8.3.6 All closed loop transfer functions shall be measured.

D.4.8.3.6.1 The excitation shall be added to the controlled plant input as shown in Figure D.1.

D.4.8.3.6.2 The response shall be measured at the output of the compensator as shown in Figure D.1.

D.4.8.3.6.3 The closed loop transfer function shall be computed as Cmd/Exc.

D.4.8.3.6.4 The required measurements and calculations may be performed externally or internally by the AMB control system using sine excitation.

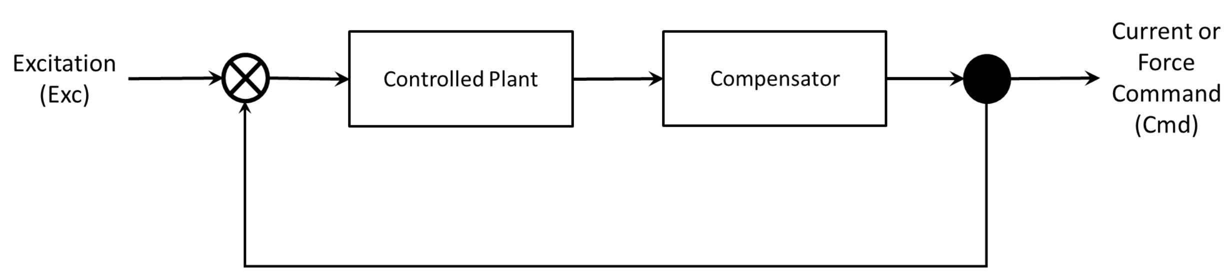


Figure D.1—Closed Loop Transfer Function Excitation and Measurement Locations

D.4.8.3.7 The results of the transfer function measurements made in D.4.8.3.6 through D.4.8.3.6.4 shall be compared with those from the analytical model specified in D.4.8.3.2 using the criteria specified in D.4.8.3.9.

D.4.8.3.8 The frequency of radial resonance peaks from the closed loop transfer function up to 125 % of N_{mc} shall not deviate from the corresponding frequency predicted by the analysis by more than ±5 %, and the measured peak amplitudes shall not be greater than 1.0 times, or less than 0.5 times the predicted amplitudes.

D.4.8.3.9 The frequency of axial resonance peaks from the closed loop transfer function up to 125 % of N_{mc} shall not deviate from the corresponding frequency predicted by the analysis by more than ±10 %.

D.4.8.3.10 After correcting the model, if required, the response amplitudes shall be checked against the limits specified in 6.8.2.10 and 6.8.2.11, and the dynamic forces shall be checked against D.4.8.2.5. The requirements of D.4.8.5.2, D.4.8.5.5, and D.4.8.7.6, as applicable, shall also be checked.

D.4.8.3.11 [●] The verification test of the rotor unbalance shall be performed only on the first rotor tested, if multiple identical rotors are purchased.

D.4.8.3.12 [●] If specified, the open loop transfer functions shall be measured in accordance with ISO 14839-3—Section 5.

D.4.8.4 Stability Analysis

D.4.8.4.1 A stability analysis as described in 6.8.4 shall be performed on all AMB supported compressors considering all modes up to 200 % of N_{mc}.

D.4.8.4.2 Acceptance Criteria

The stability analysis shall indicate that the machine, as calculated in D.4.8.5.1, shall have a log decrement greater than shown in Figure D.2:

a) has a final log decrement greater than 0.1 for all rotor modes and greater than 0.0 for all structural modes between 0 and N_{mc};

b) has a final log decrement greater than 0.0 for all modes greater than 125 % of N_{mc};

c) has a final log decrement greater than $\delta_{min\ allowable}$ given by Figure D.2 for any rotor mode between N_{mc} and 125 % of N_{mc}.

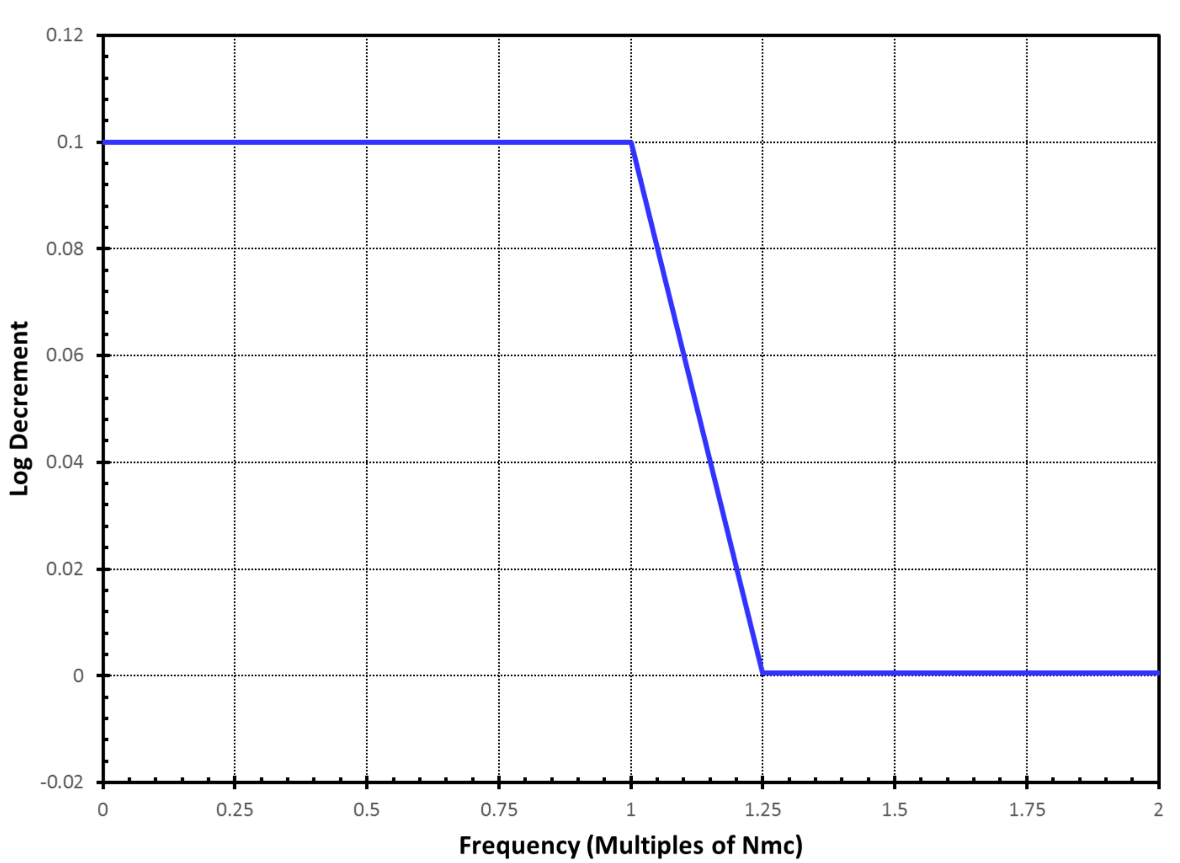


Figure D.2—Minimum Acceptable Log Dec

D.4.8.4.3 If after all practical design and retuning efforts have been exhausted to achieve the requirements of D.4.8.5.2, acceptable levels of the log decrement, δ_f, shall be agreed.

D.4.8.4.4 The sensitivity function analysis described in ISO 14839-3 shall be performed progressively, similar to the procedure described in 6.8.6.8, as part of the stability analysis.

D.4.8.4.5 The peak values of the sensitivity functions computed in D.4.8.5.4 shall fall within zone A as defined in ISO 14839-3.

D.4.8.4.6 If after all practical design and retuning efforts have been exhausted to achieve the requirements of D.4.8.5.5, acceptable levels of the peak value of the sensitivity function shall be agreed.

D.4.8.5 Axial Analysis

D.4.8.5.1 The vendor having unit responsibility shall ensure that an axial damped eigenvalue analysis of the complete coupled train is carried out and shall be responsible for directing any modifications necessary to meet the requirements.

D.4.8.5.2 A simplified lumped mass model (lumped rotating component masses, stiffnesses, and damping) is sufficient for this analysis.

D.4.8.5.3 The axial analysis shall consider all major items that affect the axial dynamics including, but not limited to, the following:

a) rotating components masses, stiffnesses, and damping;

b) the axial AMB system;

c) coupling masses, stiffnesses, and damping;

d) nonrotating structural stiffness, mass, and damping characteristics as they relate to the axial actuator and sensor, including effects of excitation frequency over the required analysis range; the vendor shall state the structure characteristic values used in the analysis and the basis for these values (for example, modal tests of similar rotor structure systems, or calculated structure stiffness values);

e) disk flexibility;

f) seals;

g) magnetic and aerodynamic centering forces and associated dynamics;

h) eddy current limitations on actuator bandwidth.

D.4.8.5.4 The damped natural frequencies and log decrements of all modes less than 100 Hz shall be calculated and shown to be stable.

D.4.8.5.5 The sensitivity function analysis described in ISO 14839-3 shall be performed for the axial system from 0 to 100 Hz.

D.4.8.5.6 The analytical sensitivity functions for modes computed in D.4.8.7.5 shall fall within zone B or better as defined in ISO 14839-3. Modes dominated by motion of a flexible coupling center spacer may be excluded from this requirement.

D.4.8.6 Vibration and Balancing

AMB systems shall be in accordance with 6.8.7 as applicable, unless otherwise agreed, and with the additional requirements as follows.

D.4.8.6.1 During the mechanical running test of the machine, assembled with the balanced rotor, operating at any speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the smaller of Equation (D.3) or 0.3 times the minimum diametral close clearance (typically the auxiliary bearing) over the range of N_{ma} to N_{mc} as shown in Figure 3.

In SI units:

$$A_{\text{vl}} = 3\left(25.4\sqrt{\frac{12{,}000}{N_{\text{mc}}}}\right) \tag{D.3a}$$

In USC units:

$$A_{\text{vl}} = 3\left(\sqrt{\frac{12{,}000}{N_{\text{mc}}}}\right) \tag{D.3b}$$

where

A_{vl} is the mechanical test vibration limit, μm (mil);

N_{mc} is the maximum continuous speed (rpm).

This paragraph replaces the requirements of 6.8.9.1.

D.4.8.6.2 At any speed greater than the N_{mc}, up to and including the trip speed of the driver, the vibration level shall not increase more than 38.1 μm (1.5 mil) above the value recorded for each probe at the N_{mc} prior to accelerating to trip.

This paragraph replaces the requirements of 6.8.9.2.

D.4.9 Bearings and Housings

D.4.9.1 General

Radial and axial bearings shall be as specified in the subsequent parts of this standard.

D.4.9.2 Radial Magnetic Bearing System

D.4.9.2.1 The load capacity of the radial bearings shall be designed with sufficient force capability to prevent contact between the rotor and any portion of the stator (including the auxiliary bearings) at all speeds from zero to trip at expected operating conditions.

D.4.9.2.2 General

Two (2) temperature sensors shall be installed in each radial bearing, one for each top quadrant coil or the coil(s) predicted to be the hottest.

D.4.9.2.2.1 One shall be used for overtemperature protection.

D.4.9.2.2.2 One shall be an installed spare.

D.4.9.3 Axial Magnetic Bearing System

D.4.9.3.1 The expected residual thrust load during normal operation shall be no more than 50 % of the axial magnetic bearing’s rated load capacity.

D.4.9.3.2 For expander-compressors covered in Part 4 with automatic thrust balancing systems, the axial magnetic bearing’s rated load capacity shall be no less than 2 times the largest residual thrust expected using the automatic thrust balancing system.

D.4.9.3.3 [●] If specified, two (2) axial position sensors shall be provided and located such that they can be used to provide rotor to stator differential expansion information.

D.4.9.3.4 Two (2) temperature sensors shall be installed in each axial bearing located in the coils opposing the design thrust direction.

D.4.9.3.4.1 Should the thrust direction reverse during normal steady-state operation, two (2) axial temperature sensors shall be installed on both sides of the thrust bearing.

D.4.9.3.4.2 One shall be used for over-temperature protection and the other as an installed spare.

D.4.9.3.5 Expected residual thrust loads for off-design operation (except for those addressed in D.4.9.4.7) shall not exceed 100 % of the bearing’s rated load capacity.

D.4.9.4 Auxiliary Bearing System

D.4.9.4.1 An auxiliary bearing system shall be provided for all machines that use AMBs.

NOTE Auxiliary bearings are considered to be a consumable machinery protective device.

D.4.9.4.2 The radial auxiliary bearing system shall include a damping mechanism.

D.4.9.4.3 Auxiliary bearing materials and lubricant(s) (if present) shall be compatible with the specified operating environment (both shop testing and in the field) and shall not adversely affect adjacent components.

D.4.9.4.4 The auxiliary bearing system shall be designed to support the rotor, without allowing any contact at close clearance locations between the rotor and stator, except at the auxiliary bearing, under any of the following conditions:

a) when the AMB system is not energized;

b) during specified transient operating events that exceed the load capacity of the AMB system;

c) during a rotor drop transient following a partial or full AMB failure;

d) during a coastdown from trip speed, under specified operating conditions, with the auxiliary bearing system providing the rotor support;

e) potential AMB failure mode(s) under which the actuator is fully energized.

D.4.9.4.5 For the purposes of D.4.9.4.4, floating ring, abradable, and compliant seals are not considered close clearance locations. The design requirements at these locations shall be agreed.

D.4.9.4.6 The vendor shall provide analytical predictions confirming that the requirements of D.4.9.4.4 are met.

D.4.9.4.7 The auxiliary bearing system shall be designed to accommodate an agreed number of momentary contacts due to specified transient operating events that exceed the load capacity of the AMB system without requiring replacement or refurbishment.

D.4.9.4.8 The auxiliary bearing system shall be designed to accommodate at least two (2) or any agreed greater number of coastdowns from trip speed under specified operating conditions without requiring replacement or refurbishment.

D.4.9.4.9 The vendor shall describe the basis for expecting the auxiliary bearing system to meet the design requirements of D.4.9.4.7 and D.4.9.4.8. This basis may include analytical simulations, as well as field and/or test stand data.

D.4.9.4.10 The vendor shall provide a means for confirming operability of the auxiliary bearing system without requiring machine disassembly.

D.5 Other AMB Subsystems and Components

D.5.1 Monitoring and Control Systems

D.5.1.1 The AMB system shall include a control system.

D.5.1.2 The control system shall consist of an enclosure containing amplifiers, control electronics, and other equipment necessary for the operation and safety of all magnetic bearings.

D.5.1.3 The control system shall provide alarm and shutdown protective logic for the magnetic bearings, auxiliary bearings, and control cabinet.

D.5.1.4 [●] If specified, an electronic digital communications link(s) shall be provided for connection to purchaser's systems utilizing the agreed format(s) and data provided.

D.5.1.5 The magnetic bearing control system shall have the capability of moving the rotor both radially and axially in order to check auxiliary bearing clearances.

D.5.1.5.1 This check shall be possible with the unit in service but not rotating.

D.5.1.5.2 Disassembly shall not be required to perform this check.

D.5.1.6 The magnetic bearing control system shall have the capability to record and display the number of large shaft excursions during machine operation.

D.5.1.6.1 Consideration shall be given to both operating speed and magnitude of the excursion in determining if an excursion is counted.

D.5.1.6.2 The count specified in D.5.1.5 shall be provided as a total since installation and as a resettable count for the installed set of auxiliary bearings.

D.5.1.7 The control system shall comply with standards EN 55011, Group 1, Class A and EN 61000-6-2.

D.5.1.8 The control system enclosure shall be designed for bottom entry wiring and shall be suitable for the area classification and location specified.

D.5.1.9 A means shall be proved for cooling control system components as required.

D.5.1.9.1 If air cooling is used, the control cabinet shall be provided with multiple cooling fans. Failure of a single fan shall not cause over-temperature shutdown to occur.

D.5.1.9.2 If water cooling is used, provision shall be made to prevent problems from condensation.

D.5.1.10 Local electronics, if required, shall be provided.

D.5.1.11 Local electronics shall be suitable for the specified area classification and for the specified ambient temperature and humidity range and vibration environment.

D.5.1.12 Vendor shall provide EMF filters on the control cabinet power supply, if required, to avoid contamination of input power by magnetic bearing power amplifiers.

D.5.1.13 Vendor's standard man-machine interface, if required, shall be provided in the English language.

D.5.1.14 A system that shall provide power to the AMB system for a minimum agreed required levitation time following loss of normal electric power supply shall be provided.

D.5.1.15 The vendor's standard uninterruptable power supply/battery backup system shall be provided and replaceable without requiring a shutdown if a customer supplied system is not utilized.

D.5.1.16 AMB parameters shall be made available for monitoring by an equipment health monitoring system.

D.5.2 Cabling

D.5.2.1 The vendor shall specify cabling requirements for the bearing power and sensor connections.

D.5.2.2 Any electrical or electronic components required to adjust for the installed length shall be included in the vendor's scope of supply.

NOTE On systems where the cable distance between the machine and the control cabinet is long [greater than 100 m (300 ft)], special consideration is given to the electrical compensation and type of cable used to ensure proper operation. Electrical compensation can also be necessary for shop testing setups.

D.5.3 Rotor Position Sensors

D.5.3.1 Sensors shall be vendor's standard design with demonstrated operating experience.

D.5.3.2 Sensor components and assembly shall be compatible with the environment to which they are exposed.

D.5.3.3 The radial position sensors shall be located as close to the radial magnetic bearing as possible where practicable.

D.6 Inspection, Testing, and Preparation for Shipment

D.6.1 No Specific Requirement

D.6.2 No Specific Requirement

D.6.3 Testing

D.6.3.1 All electronic components shall have a 24-hour burn-in prior to shipment.

D.6.3.2 The dry insulation resistance of assembled bearing power coils shall be greater than 50 megohms when tested with a 500 Volt DC megohmmeter.

D.6.3.3 [●] If specified, a "wet" bearing assembly insulation test shall be performed to agreed procedure and acceptance criteria.

D.6.3.4 The magnetic bearing control system shall be functionally tested prior to shipment.

D.6.3.5 Functional test shall include, as a minimum, connection to a simulated load and demonstration of the system's monitoring functions.

D.6.3.6 [●] If specified, static load capacity tests on all new bearing designs shall be performed.

D.6.3.7 Bearing measured load capacity shall be equal to or greater than specified requirement.

D.6.3.8 Static and dynamic tests shall be performed using cables provided by the vendor.

D.6.3.8.1 In general, these shall not be the same cables as that used in the field.

D.6.3.8.2 The vendor shall allow for any special tuning adjustments in the design.

NOTE 1 Users will consider building up the actual machine skid for the mechanical test to reduce the likelihood of field retuning.

NOTE 2 A rotor ring test can also be advisable prior to machine assembly to improve the accuracy of higher rotor modes in the model.

D.6.3.9 The sensitivity function measurement described in ISO 14839-3 (including the axial axis) shall be performed at 0 rpm prior to operating the machine for the mechanical test.

D.6.3.10 The peaks of the radial sensitivity functions measured in D.6.3.9 shall fall within zone A as defined in ISO 14839-3.

D.6.3.11 The peaks of the axial sensitivity functions measured in D.6.3.9 shall fall within zone B or better as defined in ISO 14839-3.

D.6.3.12 [●] If specified, the sensitivity function measurement described in ISO 14839-3 shall be performed at additional speed(s) with the additional measured sensitivity function peaks falling within the zones specified above.

D.6.3.13 While the equipment is operating at N_{mc}, or other speed required by the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous.

D.6.3.13.1 These data shall cover a frequency range from 0.25 to 8 times the N_{mc}.

D.6.3.13.2 If the amplitude of any discrete, nonsynchronous vibration exceeds 50 % of the allowable vibration as defined in 6.8.9.1, the purchaser and the vendor shall agree on requirements for any additional testing and on the equipment's acceptability.

This requirement replaces the requirements of 8.3.2.2.2 of Part 2 and 8.4.3.3.2 of Part 4.

D.6.3.14 [●] If specified, short-term delevitations at specified operating conditions shall be performed during mechanical test and/or full-load test as per the agreed details of this test and the procedures to be followed, including any post-test auxiliary bearing inspection(s).

NOTE The intent of this paragraph is to provide an option to use short (few seconds) delevitations at normal operating speed, followed by relevitation and normal AMB system operation, to confirm the basic operational characteristics of the auxiliary bearing system. It would be appropriate to stop the machine and perform lift checks and/or inspect the auxiliary bearings between multiple tests.

D.6.3.15 [●] If specified, a coastdown from trip speed using the auxiliary bearing system, with the AMB system inactive, shall be performed during mechanical test and/or full-load test as per the agreed details of this test and the procedures to be followed, including any post-test auxiliary bearing inspection.

NOTE If the mechanical test configuration coastdown time is significantly longer than the field coastdown time, this will not represent a valid test of the auxiliary bearing system's performance.

D.6.3.16 Damage to auxiliary bearing system components that did not compromise their ability to prevent contact at other close clearance locations, and did not cause secondary damage, does not constitute failure for the tests specified by either of D.6.3.14 or D.6.3.15.

NOTE Auxiliary bearings are considered to be a consumable machinery protective device. The AMB vendor can be consulted for guidance regarding auxiliary bearing reuse, refurbishment, or replacement following these tests.

D.7 No Specific Requirement

D.8 Field, As-installed Analyses

NOTE Due to unmodeled structural dynamics and/or process condition effects, it can be necessary to fine-tune the AMB system based on actual machine field experience during commissioning. The intent of this section is to ensure that the final rotordynamics report reflects the installed tuning.

D.8.1 The final rotordynamics report shall include analyses performed using the as-tuned AMB control system parameters at the conclusion of initial commissioning.

D.8.2 The report shall indicate if the rotordynamic analyses with the as-tuned parameters meet the applicable requirements.

D.8.3 The analyses to be updated shall not include those related to the unbalance rotor response verification test described in 6.8.3 and/or the transfer function-based procedure described in D.4.8.3.2 through D.4.8.3.10.

D.9 Reporting Requirements for Lateral and Stability Analysis

D.9.1 General

AMB systems shall have lateral analysis reports be in accordance with Annex B as applicable and with the additional requirements as follows.

D.9.2 Standard Lateral Analysis and Stability Report

D.9.2.1 AMB Data

a) General actuator and rotor component dimensions.

b) Auxiliary bearing gap(s) at 0 rpm and over the operating speed range.

c) Plot of AMB allowable force vs frequency envelope, and identification of factor of safety assumed.

d) Identification of actuator coordinate system (generally ±45° and axial).

e) Plots of AMB system displacement to force transfer functions that were used for the analytical rotordynamic predictions as amplitude and phase vs frequency (Bode plots). These shall be in physical (sensor-actuator) and actuator-actuator coordinates. Plots for cross coupling between the various axes shall be provided if there is significant coupling.

D.9.2.2 Undamped Results

a) Plot, as a minimum, a free-free map over the range of 0 to 150 % of N_{mc} and including all modes below 300 % of N_{mc}.

D.9.2.3 Unbalance Response Predictions

a) Plot predicted bearing forces relative to the AMB allowable force envelope vs speed for each unbalance response case.

D.9.2.4 Stability Analysis

a) Plots of predicted ISO 14839 sensitivity functions with twice Q_{A} applied.

b) The stability plot specified in Figure B.2, augmented to show all modes required for analysis.

c) Values of all log decrements for all modes required for analysis plotted on Figure D.2.

d) The peak values of the ISO 14839-3 sensitivity functions for each component, and the peak frequencies.

e) Plot(s) of the ISO 14839-3 sensitivity functions vs frequency with all components applied.

D.9.2.5 Axial Analysis

a) List of axial natural frequency and brief description or mode shape plot.

b) Plot of ISO 14839-3 sensitivity function for axial axis.

c) Peak value of sensitivity function plot.

D.9.2.6 Additional Plots

Predicted closed loop transfer functions, with resonance peak frequencies and values annotated, if the optional closed loop verification test has been specified in D.4.8.3.1.

D.9.2.7 Auxiliary Bearings

Analytic results specified in D.4.9.4.4 and D.4.9.4.6 confirming no contact at close clearance locations.

D.9.3 Data Required to Perform Independent Audits of Lateral Analysis and Stability Reports

D.9.3.1 [●] AMB Control/Actuator System Data to Permit Independent Analysis

If specified, the following data shall be provided to permit an independent audit of the AMB system.

a) Axial locations and angular orientations of sensors and actuators.

b) Coefficients for all required displacement to force transfer functions for lateral and axial analyses over a frequency range adequate to perform the required analyses. The force displacement functions include the effects of all dynamic systems. This should include sensor, compensator, amplifier, sample rate, computational delays, eddy current effects, etc. The actuator negative stiffness should be provided separately. These shall be provided for a coordinate system corresponding to the physical orientations of the sensors and actuators, not a transformed system (such as tilt-translate). If agreed, they may be supplied as first-order system matrices.

c) Description of any significant variations in specific transfer function coefficients due to gain scheduling or other effects. A series of overall transfer functions for different speed ranges is also acceptable.

d) Actuator negative magnetic stiffness, and where applied, if required for model.

D.9.3.2 AMB Force Envelope

a) Force vs frequency operating envelope data in tabular format with brief explanation of what specific issues were considered.

   1) A thermally rated envelope with the maximum dynamic loads that can be generated without overheating the AMB stator under expected static loads.

   2) A saturation envelope that can be generated instantaneously with representative signals in the system under expected static loads.

b) Data to permit check on reasonableness of operating force envelope. This might include, for example:

   1) actuator nominal inductances;

   2) nominal bias currents;

   3) nominal power amplifier supply voltage;

   4) nominal actuator force/current at 0 rpm for nominal radial load;

   5) actuator/rotor materials and pole face area;

   6) nominal rated power amplifier RMS current;

   7) nominal rated power amplifier peak current.

D.9.3.3 Auxiliary Bearings

a) Axial locations.

b) Type (i.e. angular contact, bushing), including dimensions, rotor/auxiliary bearing gap, coefficient of friction, geometry, lubricant type, and other pertinent information.

c) Force vs deflection curve, including the effects of hard stop if present.

d) Stiffness and damping provided by the auxiliary bearing and/or compliant mount system.

Annex E
(informative)

Guidelines for Anti-surge Control Systems

E.1 Surge in Centrifugal or Axial Compressors

Surge is a characteristic behavior of an axial or centrifugal compressor that can occur when inlet flow is reduced such that the head developed by the compressor is insufficient to overcome the pressure at the discharge of the compressor. Once surge occurs, the flow through the compressor reverses, resulting in a drastic discharge pressure drop. This flow reversal may result in compressor or system damage resulting from the following.

a) A reversal of significant mass flow that can result in large dynamic forces on the impeller or blading within the compressor, on components of the compressor exposed to large changes in axial force on the rotor such as thrust bearings, bearing, housings or their attachment to the compressor casing, and piping connected to the compressor. Left uncorrected, surge may result in fatigue damage to compressor or piping components.

b) A reversal of flow within the compressor results in hot compressed gas returning to the compressor inlet to be recompressed once flow is stabilized to a point to restore normal flow within the compressor. Left uncorrected, surge can result in ever-increasing temperatures within the compressor leading to potential rubs created by differential expansion of components within the compressor.

c) A reversal of flow may lead to process related problems that could shut down a plant.

As a result of the potential for damage to critical compressors or associated piping systems, a multifaceted approach is required. The following items should be addressed when evaluating surge prevention.

a) A prediction of the compressor operating characteristics where surge occurs is required at specified operating conditions.

b) Develop an algorithm that can use measured inputs for a control system to take corrective action to prevent surge.

c) Design a flow path other than the normal process piping that can blow off gas at the compressor discharge to atmosphere, or in cases where gas cannot be vented to the atmosphere, a recycle system to cool discharge gas and reroute it to the compressor inlet.

d) During the commissioning phase of the compressor, start-up tests should be conducted to identify either actual surge points of the compressor or the points at which the anti-surge control system responds to a reduction in the process inlet volume flow to the compressor. The ability of the anti-surge control system to prevent surge as the process inlet volume flow is further reduced should also be verified. Whether or not to validate the actual surge points in the field might depend upon how surge might upset process operations or the potential for damage to piping systems or compressor components.

e) The user should consider whether the anti-surge control system should be tied into the process alarm parameters. An alternate anti-surge response signal may be possible to provide warning to operators that process inlet volume flow is reducing and activation of the anti-surge control system is eminent.

f) In the event an anti-surge control system does not function as intended, an additional system that is designed to detect surges should be installed (see API 670). This system will alert the operator so that corrective action can be taken to get the machine out of surge or shut the machinery down.

E.2 Design Features of Anti-surge Control Systems

Following features are of high importance when designing an anti-surge control system.

E.2.1 Intelligent Control Algorithms

The control system vendor should propose a suitable control algorithm which ensures that the compressor is kept out of surge even under severe upsets. Advanced controls can include following features.

a) Combination of closed loop and open loop control. If closed loop control is not able to avoid large overshoots beyond the surge control line, the open loop control should be activated and open the anti-surge valve. This can be achieved either in step changes through analogue output or staggered/full opening through solenoid valve(s).

b) Rapid transients toward surge should be detected and the anti-surge valve should open in open loop or closed loop control before the anti-surge control line is reached.

c) Manual controlled opening of the anti-surge valve should be possible without risk of closing the valve further than allowed for surge protection.

E.2.2 Loop Response Time (e.g. Transmitter Scan Time, Controller Scan Time)

a) Optimal maximum dead time of the controller should be less than 10 ms.

b) Scan time of the anti-surge controller (measured from the change of input signal to the change of output signal) should be less than 40 ms.

c) Scan time of flow transmitter should be less than 100 ms.

d) Timing of the shutdown instruments and loops shall be predicted analytically with verification. Verification procedures are required for the owner to perform the field verification steps for proof testing.

NOTE For the majority of applications, using the DCS for surge control is not recommended due to the scan time associated with these systems.

E.2.3 Damping of Inlet Flow Signal

The measured flow typically shows fluctuating signals due to vortices at the sensing element. Damping of these signals should be avoided as this will delay the response of the anti-surge loop.

E.2.4 Sizing of the Anti-surge Valve

a) The anti-surge valve should be designed for minimum 130 % of rated flow at design pressure (~200 % surge flow). This should be verified by plotting the fully open valve resistance curve on the performance map.

b) The valve characteristic curve should be linear.

c) A solenoid operated vent should be provided for rapid opening of the anti-surge valve in case of open loop control.

d) Travel time to open through solenoid valve should be 1 to 2 seconds for full stroke.

e) Travel time for controlled opening should be 1 to 2 seconds. This can be easily achieved with hydraulic actuation and can be a challenge for some pneumatic actuators. This time would need to be considered in the system design.

f) Travel time to close the valve should be approximately 20 seconds for full stroke.

g) Valve actuator should respond without time delay, irrespective of the valve position at the start of upset.

h) Anti-surge silencer and cooler should be sized for the full valve flow at rated pressure or pressure ratio.

NOTE Anti-surge valve silencer and anti-surge cooler need to be mechanically designed for the full flow of the fully open anti-surge valve at design pressure. The excess flow to unload the compressor needs to be considered in the design. Acoustic design of silencer needs to take into account partial openings of the anti-surge valve at which its noise generation can be higher than at fully open condition.

E.2.5 Trapped Volumes

The pipe volume between compressor discharge nozzle, anti-surge valve, and check valve should be minimized. It should not exceed the volume flow which the compressor discharge handles in 0.5 seconds for axial and 1 second for centrifugal compressors.

EXAMPLE A compressor with 500,000 m^3/h (17.7 $MMft^3$/h) inlet flow and 100,000 m^3/h (3.54 $MMft^3$/h) discharge flow, feeds 28 m^3/s (988 ft^3/s) toward the discharge volume. The pipe and column volume should not exceed 14 m^3 (494 ft^3) for axial flow compressors or 28 m^3 (988 ft^3) for centrifugal compressors.

E.2.6 Discharge Check Valve

The discharge check valve is a critical item for anti-surge protection. The check valve should operate without flutter and close immediately without sticking once the compressor discharge pressure drops below the discharge header pressure. On axial compressors, installation of forced closing support (solenoid actuated pneumatic cylinder) is recommended. Installation of closing support (solenoid actuated pneumatic cylinder) is recommended when using tilting-disc type check valves.

E.2.7 Intermediate Unload Valve for Intercooled or Multi-section Compressors

Intercooled axial and centrifugal compressors with larger process volumes between the sections should be equipped with an intermediate unload valve.

E.3 Surge Detector

The surge detector should detect each surge of the compressor and initiate immediate unloading of the compressor. API 670 states the necessity of the surge detector for compressors.

Annex F
(informative)

Typical Materials for Components

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
Casing—pressure containing [1]							Typically utilize materials recognized for pressure vessel service by codes [1]
Cast	Cast iron		F11701	ASTM A278, Class 30, 40	JIS G5501	EN 1561 EN-GJL	
	Austenitic cast iron		F41002, F43010	ASTM A436, A571	JIS G5510		
	Ductile iron		F32800	ASTM A395	JIS G5502	EN 1563 EN-GJS	
	Cast steel		J13345	ASTM A216, Grades WCB, WCC	JIS G5102	EN 10213	
			J03003, J22500, J31550, J41500, J02505	ASTM A352, Grades LCB, LC2, LC3, LC4, LCC	JIS G5152	EN 10213	
			J82090, J84090, J91150	ASTM A217	JIS G5151	EN 10213	No grades listed in previous revision, grades matching these would be WC5, WC6, WC9, C5, C12, A15
	Cast stainless steel	Austenitic or duplex	J92600, J92800, J92900	ASTM A351, A743/744 Grades CF3M, CF3MA, CF8, CF8M, CF8MA	JIS G5121	EN 10213	
		Martensitic	J91540	ASTM A487 Grade CA6NM Class A and B	JIS G 5121	EN 10213	
		Ferritic or martensitic		ASTM A757 Grades E3N, D1Q1	JIS G 5152	EN 10213 SEW 685	
	Cast aluminum		A13560, A13570	ASTM A356 or A357	JIS G5151	EN 1706 AC-42000	
			A03550, A03560	ASTM B26M 355, 356	JIS H5202	EN 1706 AC-45300 AC-42000	

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
	Cast titanium		R56400, R52700	ASTM B367, Grade C3 or C4	JIS H4600 2		
Fabricated	Steel		K02801	ASTM A285, Grade C	JIS G3118		
			K01800, K02100, K02403, K03101	ASTM A516, Grade 55, 60, 65, 70	JIS G3118	EN 10028-2	
			K21703, K22103, K31718, K32018	ASTM A203, Grades A, B, D, E	JIS G3127	EN 10028-4	
			K02400, K12437	ASTM A537, Class 1 or 2	JIS G3115	EN 10028-6	
			K81340	ASTM A353, ASTM A553, Type I, II	JIS G3127	EN 10028-3	
			K03506, K03017	ASTM A266, Class 1 or 4	JIS G3202	EN 10222-4	
			K12822	ASTM A336, Class F1	JIS G3202	EN 10222-2	
			K02201, K02505, K02503	ASTM A414	JIS G3116	EN 10120	No grades previously called out
			K12766	ASTM A508, Class 5a (now: Grade 5 Class 2)	JIS G3204	20NiCrMo14-6	
			K03011, K32025	ASTM A350, Grade LF2, LF3	JIS G3205	EN 10222-3	
			K03506	ASTM A266, Class 1	JIS G3202		
			K02203	ASTM A662, Grade B	JIS G3205	EN 10028-4	
				ASTM A765, Grade IV	JIS G3201	EN 10222-4	
				ASTM A350, Grade LF6 Class 1	JIS G3201	DIN 17103	
	Stainless steel	Austenitic	S30400, S30403, S31600, S31603, S32100	ASTM A240, Type 304, 304L, 316, 316L or 321, ASTM A182, Type F304, F304L, F316, or F321	JIS G4304 JIS G4305 JIS G3214	EN 10028-7 EN 10222-5	
		Low alloy	S41500	ASTM A182, Grade F 6NM	JIS G3214	EN 10222-5	
	Aluminum		A96061, A97075	6061 or 7075 Alloy to ASTM B209, ASTM B211 or ASTM B247	JIS H4000 JIS H4040 JIS H4140		

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
			A97050	7050 Alloy to AMS 4108	JIS H4140		
Impeller							
Cast	Aluminum		A33550, A97050	ASTM B26, Alloy C355 or AL7050	JIS H5202	EN AC-45300	
			A13560, A13570	ASTM A356 or A357	JIS G5151	EN 1676 DIN1725-2	
	Precipitation hardening stainless steel		J92180, J92110	ASTM A747, Type CB7CU-1 or CB7CU-2	JIS G5121	EN 10283 SEW 410	
	Steel		J05003	ASTM A148 ASTM A487 Gr 4Q	JIS G5111		
	Stainless steel		S41000, S41500, J92500, J92800, J92600, J92900	ASTM A743/744 or A351, Grade CA15, CA6NM, CF3, CF3M, CF8, or CF8M	JIS G5121	EN 10283	
	Titanium		R50550, R50700, R56400	ASTM B367, Grade C3, C4, or C5	JIS H4600		
Fabricated	Aluminum		A96061, A97075	6061 or 7075 Alloy to ASTM B209, ASTM B211, or ASTM B247	JIS H4000 JIS H4040 JIS H4140		
			A92618	ASTM B247, Alloy 2618	JIS H4140		
			A97050, A97175	AMS 4108, Alloy 7050, 7175	JIS H4140		
	Steel		G41300, G41400, G43200	AISI/ASTM Types 4130-4140, 4320-4345	JIS G4053	EN 10083-3	
			K81340	ASTM A353, ASTM A553, Type I, II	JIS G3127	EN 10028-3	
			UNS K42339	ASTM A543	JIS G3101 SS400	EN 10025	
	Stainless steel	Austenitic	S30400, S30403, S31600, S31603, S32100	ASTM A240, Type 304, 304L, 316, 316L or 321, ASTM A182, Type F304, F304L, F316, or F321	JIS G4304 JIS G4305 JIS G3214	EN 10028-7 EN 10222-5	
		Martensitic	S40300, S41000, S41600, S42000	ASTM A473 ASTM A336, AISI/ASTM Type 403, 410, 416, 420	JIS G3214	EN 10088-3	
			S42200	ASTM A1021, Grade D, Class 2 (422)			

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
		Ni alloy steel		ASTM A522, Type I or II	JIS G3127 SL9N520	EN 10222-3	
			N07718	INCONEL 718, ASTM B637, AMS 5662	JIS G4902		
		Ni-Cu	N04400	ASTM B127, AMS 4544	JIS H4551		
	Nickel-copper alloy		N05500	Monel K-500, ASTM B 865, AMS 4676, QQ-N-286	JIS H4553	DIN 17743 17752–17754, ISO 9725	
	Precipitation hardening stainless steel		S17400, S15500	ASTM A693, A705 or A564, Types 630 or XM-12	JIS G3214 JIS G4303	EN 10250	
	Titanium		R56200	ASTM B381 Grade 5, ASTM Grade 23, ASTM F136, AMS 4928	JIS H4657	DIN 17864	Ti-6AL-4V
Shaft/Rotor components							
	Steel	Forged carbon and alloy steel	S32760, K42885, K23010	ASTM A470, Class 1, 7, or 8	JIS G3201 JIS G3204 JIS G3221	SEW 555	
		Alloy steel	G43400, G41400, G41500	AISI/ASTM Type 4340, 4140, 4150, 4345	JIS G4053	EN 10083-3	
		Carbon steel	G10400, G10500	AISI Types 1040-1050	JIS G4051	EN 10083-2	
		Alloy steel	G23300	AISI Type 2320, 2330			
			G93100	AISI Type 9310	JIS G4053		
			K32025	ASTM A350, Grade LF3	JIS G3205	EN 10222-3	
		Ni alloy steel		ASTM A522, Type I or II	JIS G3127 SL9N520	EN 10222-3	
	Stainless steel	Martensitic	S40300, S41000, S41600, S42000	ASTM A473 ASTM A336, AISI/ASTM Type 403, 410, 416, 420	JIS G3214	EN 10088-3	
			S42200	ASTM A1021, Grade D, Class 2 (422)			
			S42400	Grade F3NM, Maresist F3NM		EN 10250	
			S41500	ASTM A182, Grade F6NM	JIS G3214	EN 10250	

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
		Ferritic		ASTM A336, Grade F6	JIS G3214		
	Precipitation hardening stainless steel		S17400, S15500	ASTM A693, A705 or A564, Types 630 or XM-12	JIS G3214 JIS G4303	EN 10250	
			S66286	ASTM A638, Grade 660, Type 2			Super alloy A-286
	Nickel-copper alloy		N05500	Monel K-500, ASTM B 865, AMS 4676, QQ-N-286	JIS H4553	DIN 17743 17752–17754, ISO 9725	
	Nickel-moly-chrome alloy		N10276	Hastelloy C-276, ASTM B574, A494 Grade CW-12M-1		ISO 15156-3	
Labyrinths/ Seals [2]							
	Aluminum		A14430, A13550, A08500, A08520	ASTM B26, Alloy 443, 335, 850, 852	JIS H5202	EN 586	
			A96061, A91100, A95083	ASTM B209, Alloy 6061, 1100, 5083	JIS H4000	EN 586	
			A97175	ASTM B247, Alloy 7175			
	Brass		C67420	ASTM B16 or B21	JIS H3250	EN 12420	
			C37100	ASTM B36, B171	JIS H3100	EN 1652	
	Nickel-copper alloy		N04400	Monel 400, ASTM B564	JIS H4553	DIN 17743 ISO 9725	
	Bronze	Tin bronze	C90700, C90800	C90700, C90800		CuSn10, CuSn12	
		Nickel Silver Bronze	C97300	C97300, ASTM B505/505M			
	Stainless steel	Martensitic stainless steel	S40300, S41000, S41600, S42000	AISI/ASTM Type 403, 410, 416, 420	JIS G3214 JIS G4304 JIS G4305	EN 10088-3	
		Austenitic stainless steel	S30300, S30400, S31600	AISI/ASTM Type 303, 304, or 316	JIS G3214	EN 10088-3	
		Stainless steel (honeycomb seals)	S30400, S30403, S31600, S31603	ASTM A240, Type 304, 304L, 316 or 316L	JIS G4304 JIS G4305	EN 10028-7	

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
	Cr-Ni-Fe-Mo-Cu-Cb alloy		N08926	ASTM B462	JIS H4551	EN 10088-3	Good corrosive/ high temperature properties
	Nickel-copper alloy		N04400	Monel 400, ASTM B564, B164	JIS H4553	DIN 17743 ISO 9725	
	Nonmetallic [5]						
		PTFE (incl. carbon or mica filled) [3]	Not applicable	Fluorosint Tetron C, G, GR, or B			Typically used for process compatibility; relatively low strength
		Resin impregnated materials	Not applicable	Micarta, NEMA Grade LE, G10, G9			
		Polyamide-Imide (PAI) [3]	Not applicable	TORLON			
		Polyetherether-ketone (PEEK) [3]	Not applicable	PEEK			
		Polyarylether-ketone (PAEK) [3]	Not applicable				
Internal mechanisms and structures (non-rotor) [4]							Careful consideration to be given to primary requirements of specific component [4]
	Cast iron		F11701	ASTM A48 or A278, Class 30	JIS G5501 FC250	EN 1561 EN-GJL-250	
	Ductile iron		F32800	ASTM A536	JIS G5502	BS2789	
	Cast steel		J13345	ASTM A216, Grade WCB	JIS G5102 SCW450	EN 10213 GP240GH ISO 4991 G240 DIN 1681 GS-38	
	Steel		K02600, K02401, K02801, K01800, K02100, K02403, K03101, K42339	ASTM A36, A283, A284, A285, A516, or A543	JIS G3101 SS400	EN 10025	

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
	Stainless steel		J91650, J92500, J92800, J92600, J92900	ASTM A743/744 or A351, Grade CA15, CF3, CF3M, CF8 or CF8M	JIS G5121	EN 10213	
			S41000, S41600, S440003	ASTM A240 or ASTM A276, Type 410, 416	JIS G4303 JIS G4304 JIS G4305	EN 10088-2 EN 10088-3	
			S30400, S30403	ASTM A240, Type 304 or 304L, AISI Type 304, 304L	JIS G4304 JIS G4305	EN 10250	
			S31600, S31603	ASTM A276, Type 316/316L			
			S34700	ASTM A478, Type 347	JIS G4309		
			S32100, S31635	ASTM A182, Grade F321, F316Ti	JIS G 3214	EN 10250	
			K02203	ASTM A662, Grade B	JIS G3205	EN 10028-4	
			K12000	ASTM A633, Grade C	JIS 3106	DIN 17102	
			K06001	ASTM A729	JIS G3201 SF340A		
			K03011	ASTM A350, Grade LF6 Class 1			
			S41500	ASTM A182, Grade F 6NM	JIS G3214	EN 10250	
			J91540	ASTM A487, Grade CA6NM Class A and B	JIS G5152	EN 10213	
			J91550	ASTM A757 Grade E3N	JIS G5152	EN 10213	
			S21904, S20910, S21800	ASTM A240, A276 Nitronic 40 (XM-10), Nitronic 50 (XM-19), Nitronic 60 (Alloy 218)			Enhanced wear and galling resistance
	Aluminum		A33550	ASTM B26, Alloy 355 or C355	JIS H5202	NF EN 1676 DIN1725-2	

[a] The materials shown in this table are those commonly used by machinery manufacturers, but the list is not all inclusive nor does it imply automatic suitability for use in any application. Other suitable materials can exist and can be used. It is recommended the machinery manufacturer demonstrate suitable past experience or that proper application considerations have been met, including potential fallback options. Actual machine application (operating temperatures and process fluids) will significantly impact material selection considerations.

[b] Material designations and specifications are generally not procurement specifications. All materials should be purchased to a specification that adequately defines the required chemical and mechanical properties and manufacturing controls.

[c] The temperature limits commonly observed by machinery manufacturers are not necessarily the same as any temperature limits specified in the applicable material specifications. For this reason, application temperature limits should generally be based on successful demonstrated experience.

[d] Descriptions of UNS Types cross referenced to other material standards can also be found in *Metals & Alloys in the Unified Numbering System* co-numbered SAE HS-1086 and ASTM DS56.

[1] Casing materials should generally be materials recognized by vessel codes such as ASME, PED, HPGSL for use as a pressure-containing material.

[2] Labyrinth material considerations include the able to resist erosion due to the high velocities under the teeth and also the rotor/stator material pair should have good rubbing properties to prevent significant rotordynamic influence during light rubs or periods of wear in. A desirable condition is to also have one of the materials serve as the sacrificial element so the other material should be able to survive normal wear and tear associated with incidental labyrinth contact.

[3] These materials are not covered by comprehensive material specifications. Instead, the machinery manufacturer shall work with and supply the material vendor with expected minimum requirements or ensure the vendor's material properties meet the needs of the application.

[4] Material selection for components in this category needs to consider the primary service requirements and material property trade-offs. Resistance to erosion can be most critical for components in high-velocity flow paths, whereas wear and galling resistance can be critical for components of moving mechanisms (i.e. guide vane assemblies).

[5] Elevated temperature usage typically limited by glass transition temperature of the material.

Coatings and Wear Elements

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
Bearings, seals	Babbitt	Tin based	L13910, L13890, L13840, L13870	ASTM B23	JIS H5401		Sacrificial wear coating/lining
Bearings, seals	Babbitt	Lead based	L53585, L53565, L53346, L53620	ASTM B23	JIS H5401		Sacrificial wear coating/lining
Seals	Lead	Refined lead	L50000–L50099	ASTM B29	H2105		Sacrificial wear coating/lining
Impellers, stator and rotor components	Electroless nickel plating			AMS-2404 AMS-C-26074 ASTM B-733 ASTM-B-656 MIL-DTL-32119			Corrosion resistance, antifouling, improved lubricity, wear resistance
Impellers	Anodizing	Electrolytic passivation		MIL-A-8625 Types II, IIB, III, AMS 2471, MS 2472, AMS 2469		BS 3987 BS 5599 BS EN 2536	Wear resistance (primarily on aluminum)

Component	Material [a]	Category	UNS Designation [d]	Typical Specifications [b]	JIS Specification [b]	EN Specification [b]	Remarks
Seals, rotor, mechanism wear surfaces	Tungsten Carbide	HVOF coating					Wear resistance
	Cobalt Chrome			Stellite			Wear resistance
	CoMoCrSi	Laser clad alloy		Tribaloy T-800 Tribaloy T-900			Cobalt based-Laves phase Alloy
Stator, seals	Polymer based	Flame spray abradable coating	Not applicable	Oerlikon Metco, Praxair (proprietary blends)			Sacrificial wear coating/lining
Stator, seals	Nickel based	Flame spray abradable coating	Not applicable	Oerlikon Metco, Praxair (proprietary blends)			Sacrificial wear coating/lining
Rotor, impeller, stator, seals	Aluminum based	Flame spray abradable coating	Not applicable	Oerlikon Metco, Praxair (proprietary blends)			Sacrificial wear coating/lining
	Ceramic/ Zirconia	Flame spray abradable coating					
	Organic/ Fluoropolymer	Ambient spray/ Bake		PTFE, FEP, PFA, ETFE			Antifouling/ Chemical resistance
	Solvent/ Fluoropolymer	Ambient spray/ Bake		Teflon S			Dry film lubrication
	Inconel	HVOF coating					
	Chrome plating						
	Nickel electroplating						

[a] The materials shown in this table are those commonly used by machinery manufacturers, but the list is not all inclusive nor does it imply automatic suitability for use in any application. Other suitable materials can exist and can be used. It is recommended the machinery manufacturer demonstrate suitable past experience or that proper application considerations have been met, including potential fallback options. Actual machine application (operating temperatures and process fluids) will significantly impact material selection considerations.

[b] Material designations and specifications are generally not procurement specifications. All materials should be purchased to a specification that adequately defines the required chemical and mechanical properties and manufacturing controls.

[c] The temperature limits commonly observed by machinery manufacturers are not necessarily the same as any temperature limits specified in the applicable material specifications. For this reason, application temperature limits should generally be based on successful demonstrated experience.

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[1] Casing materials should generally be materials recognized by vessel codes such as ASME, PED, HPGSL for use as a pressure-containing material.

[2] Labyrinth material considerations include the able to resist erosion due to the high velocities under the teeth and also the rotor/stator material pair should have good rubbing properties to prevent significant rotordynamic influence during light rubs or periods of wear in. A desirable condition is to also have one of the materials serve as the sacrificial element so the other material should be able to survive normal wear and tear associated with incidental labyrinth contact.

[3] These materials are not covered by comprehensive material specifications. Instead, the machinery manufacturer shall work with and supply the material vendor with expected minimum requirements or ensure the vendor's material properties meet the needs of the application.

[4] Material selection for components in this category needs to consider the primary service requirements and material property trade-offs. Resistance to erosion can be most critical for components in high-velocity flow paths, whereas wear and galling resistance can be critical for components of moving mechanisms (i.e. guide vane assemblies).

[5] Elevated temperature usage typically limited by glass transition temperature of the material.

Annex G
(informative)

Full-load/Full-pressure/Full-speed Testing

G.1 General

This annex discusses the more typical optional load tests available for centrifugal compressors. These tests, due to their complexity, should be fully discussed, with objectives defined, prior to equipment order with the vendor. Test conditions, goals, and requirements should be discussed, highlighting risk mitigation intended by the test.

G.2 Type I Test

This test should not be confused with a full-load/full-pressure (FLFP) hydrocarbon test. This is a hydraulic performance test on the SPECIFIED gas at certified point inlet conditions and speed with limited permissible deviations per ASME PTC 10. Mechanical integrity under actual performance conditions is demonstrated. The Type I test may be performed using a shop driver or the contract driver. Typically, contract lube-oil and seal systems are utilized. This is a very special test with specific requirements. It is recommended that all test requirements/objectives (such as number and location of test points, acceptance criteria, gas property equations of state, speeds etc.) be identified and agreed well in advance, in writing, between the client and vendor.

For a Type I test, the test restrictions are based on ASME PTC 10 Tables 3.1 and 3.2. The Type I test is conducted at the design speed of the certified condition as identified during the Type II inert gas performance test. Five data points are read from capacity limit to within 10 % of surge (inside the proposed surge control line); units are typically NOT purposely surged during this test. Units having more than one section may be tested one section at a time dependent on the thrust load and gas makeup in the two sections. If the same gas is utilized in each section, the vendor may consider testing both sections simultaneously.

The vendor may not be able to use the exact specified gas (most often it is a gas blend of local pipeline gas with commercially available gases such as propane, carbon dioxide, and nitrogen). The gas blend is typically designed to match the specified inlet density and k value at the test inlet temperature. Under these conditions, the observed values of head, pressure ratio, and horsepower will be the same as observed during operation in the field under specified conditions. This test also simulates any aerodynamic excitation imparted to the rotor/bearing system relative to field operation at the specified operating conditions.

If a contract driver is to be used, review of the test site ambient conditions and/or facility restrictions need to be reviewed with the vendors test department personnel. For example, a gas turbine may not be able to generate design power at the elevation and temperature of the vendor's test facility. The steam conditions required, for a contract steam turbine, may exceed test boiler capability or electrical facilities, for a contract motor, may not be adequate.

The contract lube and seal systems are typically used especially for train tests.

Typical acceptance criteria:

— Observed head will be within ±2 % of specified head at the specified speed established via the Type II test.

— Observed brake horsepower will be ≤ 103 % of power established by Type II test.

— Vibration levels will be < 150 % of the allowable vibration during the mechanical test.

Some questions that may arise:

— Why is the horsepower ≤ 103 % of the established horsepower at specified conditions based on the Type II test and not ≤ 104 % of the guaranteed value?

Typically, the instrumentation used is not as accurate as the instrumentation used for the Type II test. For example, static pressure is measured during the Type I test vs total pressure during Type II testing. Thermowells are used instead of total temperature probes inserted directly in the gas stream. Gas property uncertainties of the specified test gas may contribute to errors. The gas properties of Type II test mediums are well known, whereas the properties of hydrocarbon mixtures are predicted.

— What equations of state are used to predict the gas properties?

Vendor will evaluate various equations of state for the specified gas and select, with discussion and agreement with the client, for the best equation for the particular application. Typically, BWRS (Benedict-Webb-Rubin-Starling), Lee-Kesler, SRK (Soave-Redlich-Kwong), or Peng-Robinson are considered.

— Will the compressor be run back into surge to establish the turndown/stability?

This is not done. To demonstrate that the unit has adequate stability, a data point(s) is normally taken at the surge control line to demonstrate rotordynamic stability.

— What level of nonsynchronous vibration is acceptable?

This is a complicated question, and the answer is usually dependent on what is causing the nonsynchronous vibration. Whereas some subsynchronous vibration may be acceptable at the 1st natural frequency, purchasers may require that no vibrations associated with stall are permitted. This discussion should be held with the vendor.

G.3 FLFP Hydrocarbon Test

This is a mechanical integrity test and not a hydraulic performance test. This test is typically 4 hours in duration with the unit at design DISCHARGE pressure and design HORSEPOWER at N_{mc} (max continuous speed). Either a shop driver or the contract driver may be used. Design inlet temperature and pressure may not be the same as specified. Typically, the design molecular weight is matched by blending local pipeline gas with CO_2. However, a lighter than design mixture may be used to facilitate operation. For example, a mole weight less than design (or heavier) may be used to achieve both design discharge pressure and horsepower simultaneously. In some cases, matching discharge pressure and horsepower simultaneously is not possible. In these cases, the test conditions representing the worst-case scenario for whatever risk is being addressed by the test should be discussed and agreed with the vendor. Vibration acceptance levels are typically higher than those specified for the low-pressure testing defined in the body of this standard.

The test is run at one operating condition throughout the test (unless discharge pressure and horsepower cannot be met simultaneously). This test also produces aerodynamic excitation imparted to the rotor/bearing system; however, the level may not be an exact match to field operation at the specified operating conditions.

If a contract driver is to be used a review of the test site ambient conditions and/or facility restrictions need to be made with the vendor. For example, a gas turbine may not be able to generate design power at the elevation and temperature of the vendor's test facility. The steam conditions required, for a contract steam turbine, may exceed test boiler capability or electrical facilities; for a contract motor, may not be adequate.

The contract lube and seal systems may be used (or required to be used).

All test objectives and acceptance criteria need to be documented before final quotation of such a test.

Typical questions:

— Will the unit be surged during the test run?

  No. The unit is operated at a single flow point on the compressor map.

— Will the performance of the unit be guaranteed?

  No. The unit is operated at a volume reduction ratio other than design. The performance is monitored relative to the predicted performance on the test blend, but no tolerances or guarantees are typically placed on the observed parameters.

G.4 FLFP Inert Gas Test

This is a mechanical integrity test NOT a hydraulic performance test. This test is 4 hours in duration with the unit at design DISCHARGE pressure and design HORSEPOWER at N_{mc} (max continuous speed). Either a shop driver or the contract driver may be used. Design inlet temperature and pressure may not be the same as specified. Typically, the test molecular weight is lower than design to keep the final discharge temperature below maximum allowable levels as inert gases available have a higher k value than the design gas. In some cases, matching discharge pressure and horsepower simultaneously is not possible. In these cases, the discharge pressure is matched for 2 hours, then the horsepower is matched for the remaining 2 hours. Vibration acceptance levels are typically higher than those specified for the low-pressure testing defined in the body of this standard.

Inert gases utilized are helium, nitrogen, helium-nitrogen mixtures, CO_2, and CO_2-nitrogen mixtures.

The test is run at one operating condition throughout the test. This test also produces aerodynamic excitation imparted to the rotor/bearing system; however, the level may not be an exact match to field operation at the specified operating conditions. Location of this point on the operating map should be discussed with respect to destabilizing forces or stall regimes.

If a contract driver is to be used, a review of the test site ambient conditions and/or facility restrictions need to be made with the vendor. For example, a gas turbine may not be able to generate design power at the elevation and temperature of the vendor test facility. The steam conditions required, for a contract steam turbine, may exceed test boiler capability or electrical facilities; for a contract motor, may not be adequate.

Contract lube and seal systems may be used (or required to be used).

All test objectives and acceptance criteria should be documented.

Typical questions:

— Will the unit be surged during the test run?

  No. The unit is operated at a single flow point on the compressor map.

— Will the performance of the unit be guaranteed?

  No. The unit is operated at a volume reduction ratio other than design. The performance is monitored relative to the predicted performance on the test blend, but no tolerances or guarantees are to be placed on the observed parameters.

G.5 Stability Measurements with PTC-10 Type I, FLFP Inert or Hydrocarbon Gas Test

With similar objectives to the unbalance response verification test, this test option provides a measure of the stability of a compressor's rotor system while operating at load under inert or hydrocarbon gas test conditions with the same limitations as noted above. While several of the above tests can only demonstrate whether a machine is stable (free of shaft whip or oil whirl vibrations) at the testing conditions, this test option quantifies the machine's stability level (log decrement) while operating under load. If stability verification testing is performed during the mechanical run test or in a high-speed balance bunker, the measurements provide evaluation of the predicted base log decrement that is dictated by the rotor and bearing system.

To perform the measurements, many different options exist in terms of the excitation devices and techniques, as well as the methods used for estimating the log decrement from the measurement data. Testing using a temporarily mounted, magnetic exciter is a proven excitation method and provides a high signal-to-noise ratio for measurement accuracy. It is important that the exciter be designed for ease of installation and removal, minimal alteration of the machine's balance and rotordynamics, and with sufficient force capacity and bandwidth to excite the mode at the test conditions.

Relying on ambient excitations generated within the machine during testing, operational modal analysis requires no installation of a temporary magnetic exciter. Operational modal analysis is used to identify the modal parameters of a system solely from measurement of radial vibration response due to ambient excitations. Because these ambient excitations are unknown beforehand, there is no guarantee that they will sufficiently excite the mode(s) of interest. The specifics of the FLFP test with need to be discussed with the vendor as the test conditions may be set up slightly different to better match the field condition.

Only a few identification techniques have demonstrated reliable accuracy to estimate the log decrement from the measured time or frequency domain data. Because rotor modes are often in close proximity, multiple-degree-of-freedom techniques, which do not rely on the assumption of only a single mode being excited, are recommended.

All the specifics of the stability measurement test process and procedures need to be discussed with the vendor, including acceptance criteria and the desired test conditions. One question often asked is as follows: "How do the measurements compare to the predicted stability levels?" To make a valid comparison, the test conditions need to be modelled in the rotordynamic prediction to obtain the appropriate damping or instability forces present in the compressor. This should include any modification to the bearing support structure dynamics needed to accurately model the test setup.

Annex H
(normative)

Basic Requirements for Dynamic Simulation Studies

H.1 Purpose

A system dynamic simulation shall be performed for compressor systems to study the dynamic response of the compressor to transient conditions and process changes/upsets.

NOTE A dynamic simulation can be used to estimate the possibility of surge during start-up, shutdown, and operation. The simulation can also estimate start-up characteristics to validate driver sizing, and identify potential process operational instabilities and assist in control concept verification.

H.2 Scope

H.2.1 If specified in 7.3.2.4, a dynamic simulation study shall be completed.

H.2.2 The default simulation scope shall include the items listed in Table H.1. Additional scenarios based on specific application concerns shall be specified by the purchaser.

Table H.1—Default Simulation Scope Items

Trip from rated point
Unloaded trip from rated point (axial flow compressor)
Normal stop from rated point
Trip from turndown (surge control line) point
Unloaded trip from turndown point (axial flow compressor)
Normal stop from turndown (SCL) point
Normal start-up
Start-up from settle out (restart)
Sudden opening of anti-surge valve during compressor operation
Sudden closure of inlet block valves during compressor operation—automatic valves only
Sudden closure of outlet block valves during compressor operation—automatic valves only

H.2.3 If specified, the dynamic simulation study shall validate the driver sizing for start-up under specified conditions.

H.2.4 If specified, the dynamic simulation study shall validate the control system design:

— operating conditions and control concept verification—change and interaction with other equipment;

— expose compressor system to process upset (operating point moves towards surge);

— change of conditions (operating points, gas composition, etc.);

— how does the equipment change from one operating condition to another;

— interaction to system and other equipment;

— multicompressor interaction—compressors in parallel, interaction with reciprocating compressors.

H.3 Bounds of the Model

H.3.1 Purchaser shall specify the bounds of the model.

NOTE 1 The model includes items that can impact the dynamic response of the system including upstream and downstream process components (scrubbers, pipes, side-streams, cooler, heater, etc.) to a point where the pressure and flow do not impact the compressor operation.

NOTE 2 This is of special importance with parallel compressors. If suction and discharge header are the boundary limits and thus pressure at the headers is maintained constant, any interaction between the compressors cannot be investigated.

H.3.2 Timeline

Simulation schedule shall be agreed. If the simulation is based on preliminary data, the schedule shall define dates when changes can be incorporated into the final design.

NOTE To benefit from the simulation results in system design, the study results need to be available before detail engineering is closed. This requires that the simulation study be based on preliminary design data.

H.4 Simulation Input Data to Be Provided After Contract Award

H.4.1 Purchaser Model Data

Following shall be defined by the purchaser prior to the start of the modeling work:

a) general description of the process in which the compressor system operates;

b) PFDs and P&IDs;

c) heat and material balance;

d) as a minimum, volumes of the segments within the bounds of the model;

   — optional: to also provide isometrics of the relevant piping;

e) compressor datasheet;

f) compressor performance curves (compressor map);

g) (combined) rotational inertia of driver, gearbox, couplings, and compressor rotor, where applicable;

h) driver torque as a function of rotational speed;

i) datasheets and drawings for relevant static equipment, such as vessels, filters, heat exchangers, including as a minimum pressure drop or resistance coefficients, volumes, and duty;

j) equipment datasheets and drawings for relevant dynamic equipment, such as check valves and control valves, including as a minimum the valve Cv and valve characteristic, capacity, travel time for opening and closing, dead times;

k) description of compressor control philosophy and anti-surge control narrative;

l) description of any process control item that can be activated as a result of the conditions experienced during the scenarios to simulate;

m) description of any additional conditions or scenarios not included in the table above, defined by the operating point of the compressor at the start of the simulation and the narrative of events to be simulated.

H.4.2 Vendor Model Data

Preliminary design data supplied by vendor prior to the start of the modeling work:

a) general description of the process in which the compressor system operates;

b) PFDs and P&IDs;

c) compressor datasheet;

d) compressor performance curves (compressor map);

e) heat and material balance;

f) preliminary volumes of static equipment and piping systems.

H.5 Final Report of Simulation Study

A final report of the results shall include as a minimum:

a) simulation block diagram showing all simulated modules with all simulated process values;

b) task of the simulation study as defined by the purchaser and as considered by the vendor;

c) all model data shall be stated in the report;

d) summary of simulation runs performed;

e) simulation results in the form of time-based plots and/or x/y plots;

f) description of each simulation run and short discussion of the simulation results per simulation run;

g) executive summary.

Annex I
(informative)

Contract Documents and Engineering Design Data

I.1 If specified by the purchaser in I.1.2, the contract documents and engineering design data shall be supplied by the vendor, as listed in this annex.

I.1.1 The information to be furnished by the vendor is specified in I.2 and I.3.

I.1.2 The data shall be identified on transmittal (cover) letters, title pages, and in title blocks, or other prominent position on the drawings, with the following information:

a) the purchaser/owner's corporate name;

b) the job/project number;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

e) any other identification specified in the inquiry or purchase order;

f) the vendor's identifying proposal number, shop order number, serial number, or other reference required to completely identify return correspondence.

I.1.3 A coordination meeting shall be held, preferably at the vendor's plant, within an agreed time after the purchase commitment.

I.1.4 The vendor shall prepare and distribute an agenda prior to this meeting, which as a minimum, shall include discussion of the following items:

a) the purchase order, scope of supply, unit responsibility, subvendor items, and lines of communication;

b) the datasheets;

c) applicable specifications and previously agreed exceptions;

d) schedules for transmittal of data, production, and testing;

e) the quality assurance program and procedures;

f) inspection, expediting, and testing;

g) schematics and bills of material for auxiliary systems;

h) the general arrangement of equipment, piping, and auxiliary systems; operating and maintenance access areas shall be reviewed; access for any parts required for maintenance shall be detailed;

i) coupling selections and rating;

j) thrust- and journal-bearing sizing, estimated loading, and specific configurations;

k) seal operation and controls;

l) the rotordynamics analysis and data (lateral, torsional, and transient torsional, as required);

m) machine performance for normal and other specified conditions and other operating conditions, such as start-up, shutdown, and any operating limitations;

n) instrumentation and controls;

o) items for design reviews;

p) other technical items.

I.1.5 [●] If specified, in addition to the coordination meeting, a design audit/review meeting shall be held at the vendor's plant after the coordination meeting to allow for detailed technical information review.

I.1.6 The purchaser shall prepare a list of items required for review and distribute the agenda prior to the meeting.

I.2 Proposals

I.2.1 General

I.2.1.1 The vendor shall forward the original proposal with the specified number of copies to the addressee specified in the inquiry documents.

I.2.1.2 The proposal shall include, as a minimum, the data specified in I.2.2 through I.2.4 and a specific statement that the equipment and all its components are in strict accordance with this standard.

I.2.1.3 If the equipment or any of its components or auxiliaries are not in strict accordance, the vendor shall include a list that details and explains each deviation.

I.2.1.4 The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs.

I.2.1.5 All correspondence shall be clearly identified in accordance with I.1.2.

I.2.2 Drawings

I.2.2.1 The proposal drawings indicated on the VDDR Form (see Annex B in Parts 2, 3, or 4 as applicable) shall be included in the proposal. As a minimum, the following shall be included:

a) a general arrangement or outline drawing for each machine train or skid-mounted package, showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights, and the largest maintenance weight for each item; the direction of rotation and the size and location of major purchaser connections shall also be indicated;

b) cross-sectional drawings, of major equipment, showing the details of the proposed equipment;

c) representative schematics of all auxiliary systems, including lube-oil, seal-oil, or self-acting dry gas, control, and electrical systems; bills of material shall be included;

d) sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries. [This information may be included on the drawings specified in item a) above.]

I.2.2.2 If typical drawings, schematics, and bills of material are used, major design deviations shall be clearly marked on the drawings.

I.2.2.3 They shall be marked up to show the expected weight and dimensions to reflect the actual equipment and scope proposed.

I.2.3 Technical Data

The following data shall be included in the proposal:

a) the purchaser's datasheets with complete vendor's information entered thereon and literature to fully describe details of the offering;

b) the predicted noise data (6.1.3.13);

c) the VDDR Form (see Annex B in Parts 2, 3, or 4 as applicable) indicating the schedule according to which the vendor agrees to transmit all the data specified;

d) a schedule for shipment of the equipment, in weeks after receipt of an order;

e) a list of major wearing components, showing any interchangeability with the owner's existing machines;

f) a list of spare parts recommended for commissioning/start-up and normal maintenance purposes;

g) a list of the special tools furnished for commissioning and maintenance;

h) a description of any special weather protection and winterization required for start-up, operation, and periods of idleness, under the site conditions specified; this description shall clearly indicate the protection furnished by the purchaser as well as that included in the vendor's scope of supply;

i) a complete tabulation of utility requirements, e.g. steam, water, electricity, air, gas, lube oil (including the quantity and supply pressure of the oil required and the heat load removed by the oil), and the nameplate power rating and operating power requirements of auxiliary drivers; approximate data shall be clearly indicated as such;

j) a description of any optional or additional tests and inspection procedures for materials as required;

k) a description of how special requirements are addressed, whether specified in the purchaser's inquiry or as mandated in this standard;

l) a list of machines, similar to the proposed machine(s), that have been installed and operating under conditions analogous to those specified in the inquiry;

m) any start-up, shutdown, or operating restrictions required to protect and operate the equipment;

n) list of any components that can be construed as being of alternative design to this standard, hence requiring purchaser's acceptance;

o) a summary of the materials of construction, including hardness for materials exposed to H_2S (see 6.2.1.6 or 6.2.1.7) and a detailed description of the impeller (type of construction, materials, and method of attachment to the shaft) or blade;

p) if oil seals are supplied, the maximum seal buffer gas rates and rated or expected inner seal-oil leakage rates, if applicable, shall be supplied; the inner seal-oil leakage shall be given on the basis of volume per day per machine at design gas or oil differential pressures and normal machine speed;

q) if self-acting dry gas seals are supplied, expected seal gas(s) requirements and vent flows shall be given for all specified operating conditions including start-up, shutdown, and settle-out;

r) if clearance seals are supplied, expected and guarantee buffer injection and eduction flows as applicable shall be supplied for all specified operating conditions including start-up, shutdown, and settle-out;

s) maximum and minimum allowable seal pressures for each compressor;

t) if heat exchangers are furnished by the vendor, data for the purchaser's heat and material balances shall be supplied;

u) drawings, details, and descriptions of the operations of instrumentation and controls, as well as the makes, materials, and types of auxiliary equipment; the vendor shall also include a complete description of the alarm and shutdown facilities provided;

v) the minimum length of straight pipe required for proper flow characteristics at the inlet and at any side inlet connection;

w) a statement of the manufacturer's capability regarding testing (including performance testing) of the compressor and any other specified items on the train; details of each optional test specified shall be included.

I.2.4 Curves

I.2.4.1 Performance curves shall be submitted for each process section of each casing as well as an overall curve for the train.

I.2.4.1.1 These curves shall encompass the map of operations, with any limitations indicated thereon.

I.2.4.1.2 All curves shall be marked "PREDICTED."

NOTE A process section is one or more impellers separated by an inlet or extraction connection to process or heat exchangers.

I.2.4.2 Curves for variable-speed compressors shall include the following: discharge pressure; power; polytropic head; and polytropic efficiency vs inlet capacity (from predicted surge point to capacity limit) at minimum operating speed and 80 %, 90 %, 100 %, and 105 % speed, indicating the effect of specified inlet pressures, temperatures, and molecular weights.

I.2.4.3 Any specified operating points shall be noted within the envelope of the performance curve predicted.

I.2.4.4 Curves and data for fixed-speed compressors shall include the following:

a) discharge pressure; power; polytropic head; and polytropic efficiency vs capacity (from surge point to capacity limit) at normal speed, indicating the effect of specified molecular weights, suction pressures, and temperatures; alternate operating conditions requiring throttling shall be shown;

b) speed vs torque required for acceleration of the train to operating speed; moment of inertia (referenced to motor speed) and initial starting conditions assumed shall be recorded on the curve;

c) motor torque vs speed at rated voltage and at 80 % of rated voltage;

d) motor current vs speed at rated voltage and at 80 % of rated voltage;

e) estimated times for acceleration to rated speed for throttled suction and for open suction at 80 % of the nameplate motor voltage;

f) curves showing performance of VIGVs at variable-vane settings covering the entire allowable map of operation (if supplied).

I.2.5 Optional Tests

The vendor shall furnish an outline of the procedures used for each of the special optional tests that have been specified by the purchaser or proposed by the vendor.

I.3 Contract Data

I.3.1 General

I.3.1.1 Contract data shall be furnished by the vendor in accordance with the agreed VDDR Form (Annex B of Parts 2, 3, or 4 as applicable).

I.3.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of drawing certification, identification data specified in I.1.2, revision number, and date and title.

I.3.1.3 Similar information shall be provided on all other documents including subvendor items.

I.3.1.4 The drawings and data furnished by the vendor shall conform to I.3.1.4.1 to I.3.1.4.3.

I.3.1.4.1 The drawings and data shall contain the needed information together with the manuals specified in I.3.5 to permit the purchaser to install, operate, and maintain the equipment covered by the purchase order.

I.3.1.4.2 All contract drawings and data shall be clearly legible (8-point minimum font size, even if reduced from a larger size drawing).

I.3.1.4.3 The drawings and data shall cover the scope of the agreed VDDR Form and shall satisfy the applicable detailed descriptions in Annex D of the applicable chapter.

I.3.1.5 The purchaser shall review the vendor's data in accordance with I.3.1.5.1 to I.3.1.5.3.

I.3.1.5.1 The review shall be completed within the agreed time frame.

I.3.1.5.2 This review shall not constitute permission to deviate from any requirements in the order unless specifically agreed in writing.

I.3.1.5.3 The vendor shall furnish vendor-certified copies.

I.3.1.6 A complete list of vendor data shall be included with the first issue of major drawings.

I.3.1.6.1 This list shall contain titles, drawing numbers, and a schedule for transmittal of each item listed.

I.3.1.6.2 This list shall cross-reference data with respect to the VDDR Form in Annex B of Parts 2, 3, or 4 as applicable.

I.3.2 Curves and Datasheets

I.3.2.1 Curves

I.3.2.1.1 The vendor shall provide complete performance curves to encompass the allowable map of operations, with any limitations indicated.

I.3.2.1.2 The curves shall comply with the requirements of I.3.2.1.2 through I.3.2.1.7.

NOTE The allowable map of operations can include multiple operating speeds, variable stationary components such as stators or guide vanes, or other means to create a complete operating map.

I.3.2.1.3 All curves submitted prior to final performance testing shall be marked "PREDICTED."

I.3.2.1.4 If a performance test is specified, the vendor shall provide test data for all test points.

I.3.2.1.4.1 Performance curves shall be recalculated and submitted when the test has been completed.

I.3.2.1.4.2 The surge points shall be shown on the performance curves.

I.3.2.1.4.3 These curves shall be marked “TESTED.”

I.3.2.1.5 For compressors that have a back-to-back impeller arrangement, the vendor shall furnish a curve showing the expected loading on each side of the thrust bearing vs any combination of the differential pressures across the low-pressure and high-pressure sections of the casing.

I.3.2.1.6 [●] If specified, the vendor shall supply curves of balance piston line differential pressure vs thrust load.

I.3.2.1.7 The vendor shall supply balance piston leakage based on design clearances and twice design clearances for the rated condition.

I.3.3 Datasheets

I.3.3.1 The vendor shall provide full information to enable completion of the datasheets for the train and auxiliary equipment, first for “as-purchased” and then for “as-built.”

I.3.3.2 This shall be done by the vendor correcting and filling out the datasheets and submitting copies to the purchaser. Datasheets are available in Annex A in Parts 2, 3, or 4 as applicable.

I.3.4 Progress Reports

I.3.4.1 [●] The vendor shall submit progress reports to the purchaser at the intervals specified.

I.3.4.2 Planned and actual dates and the percentage completed shall be indicated for each milestone in the schedule.

I.3.4.3 [●] If specified, 1 week prior to the start of assembly, the vendor shall issue a “Tail End Schedule” bi-weekly including scheduled and actual completion dates of major activities.

NOTE The schedule can include major assemblies, subassemblies, test setup, testing, paint, packing, and shipment preparation.

I.3.5 Parts Lists and Recommended Spares

I.3.5.1 The vendor shall submit complete parts lists for all equipment and accessories supplied per I.3.5.1.1 through I.3.5.2.

I.3.5.1.1 These lists shall include part names, manufacturers’ unique part numbers, and materials of construction (identified by applicable international standards).

I.3.5.1.2 Each part shall be completely identified and shown on appropriate cross-sectional, assembly-type cutaway, or exploded-view isometric drawings.

I.3.5.1.3 Interchangeable parts shall be identified as such.

I.3.5.1.4 Parts that have been modified from standard dimensions or finish to satisfy specific performance requirements shall be uniquely identified by part number.

I.3.5.2 The vendor shall indicate on each of these complete parts lists all those parts that are recommended as commissioning/start-up or maintenance spares and the recommended stocking quantities of each including spare parts recommendations of subvendors that were not available for inclusion in the vendor’s original proposal.

I.3.6 Installation, Operation, Maintenance, and Technical Data Manuals

I.3.6.1 General

I.3.6.1.1 The vendor shall provide sufficient written instructions and all necessary drawings to enable the purchaser to install all of the equipment covered by the purchase order.

I.3.6.1.2 This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in I.1.2, a table of contents, and an index sheet for each section, a complete list of the enclosed drawings by title, drawing number, and revision.

I.3.6.1.3 The manual pages and drawings shall be numbered.

I.3.6.1.4 The manual or manuals shall be prepared specifically for the equipment covered in the purchase order. “Typical” manuals are unacceptable.

I.3.6.1.5 [●] If specified, a draft manual(s) shall be issued to purchaser 8 weeks prior to mechanical testing for review and comment.

I.3.6.1.6 Electronic copies shall be provided.

I.3.6.1.7 [●] If specified, hard copies as well as electronic copies shall be provided.

NOTE Refer to the VDDR Form for number of copies.

I.3.6.2 Installation Manual

I.3.6.2.1 All information required for the proper installation of the equipment shall be compiled in a manual.

I.3.6.2.2 It may be separate from the operation and maintenance instructions.

I.3.6.2.3 This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centers of mass, rigging procedures, and other installation data.

I.3.6.2.4 All drawings and data specified in I.2.2 and I.2.3 that are pertinent to installation shall be included as part of this manual.

I.3.6.2.5 One extra manual, over and above the specified quantity, shall be included with the first equipment shipment.

NOTE Refer to API 686 and the VDDR for installation requirements.

I.3.6.3 Operating and Maintenance Manual

I.3.6.3.1 A manual containing all required operating and maintenance instructions shall be supplied at shipment. In addition to covering operation at all specified process conditions.

I.3.6.3.2 This manual shall also contain separate sections covering operation under any specified extreme environmental conditions.

I.3.6.4 [●] Technical Data Manual

If specified, the vendor shall provide the purchaser with a technical data manual at shipment. See description in Annex B of Parts 2, 3, or 4 as applicable for minimum requirements of this manual.

Bibliography

[1] API Standard 520, *Sizing, Selection, and Installation of Pressure-relieving Devices, Part 1—Sizing and Selection*, Ninth Edition

[2] API Standard 672, *Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services*

[3] API Standard 673, *Centrifugal Fans for Petroleum, Chemical and Gas Industry Services*

[4] AGMA 908, *Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth*

[5] ASME B18.12-2012, *Glossary of Terms for Mechanical Fasteners*

[6] ASTM A515/A515M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

[7] ASME B31.3, *Process Piping*

[8] ASME *Boiler and Pressure Vessel Code, Section VIII: Rules for Construction of Pressure Vessels*

[9] ISO 3740, *Acoustics—Determination of sound power levels of noise sources—Guidelines for the use of basic standards*

[10] ISO 3746, *Acoustics—Determination of sound power levels and sound energy levels of noise sources using sound pressure—Survey method using an enveloping measurement surface over a reflecting plane*

[11] ISO 7268, *Pipe components—Definition of nominal pressure*

[12] ISO 10494, *Turbines and turbine sets—Measurement of emitted airborne noise—Engineering/survey method*

[13] SAE HS-1086/ASTM DS56, *Metals & Alloys in the Unified Numbering System*

Axial and Centrifugal Compressors and Expander-compressors
Part 2—Nonintegrally Geared Centrifugal and Axial Compressors

1 Scope

This part of API 617 specifies requirements for nonintegrally geared centrifugal and axial compressors, in addition to the general requirements specified in API 617, Part 1. These machines do not have gears integral with their casing.

NOTE See API 672 for packaged plant and instrument air compressors.

2 Normative References

Referenced documents indispensable for the application of this document are listed in Section 2 of Part 1.

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

For the purposes of this document, the terms, definitions, acronyms, abbreviations, and symbols given in Part 1 apply.

4 Dimensions and Units

The dimensional and unit requirements of Part 1 shall apply.

5 Requirements

5.1 Statutory Requirements

The statutory requirements of Part 1 shall apply.

5.2 Unit Responsibility

The unit responsibilities of Part 1 shall apply.

6 Basic Design

6.1 Performance

6.1.1 The sectional head-capacity characteristic curve shall rise continuously from the rated point to predicted surge.

6.1.2 For any speed, the minimum operating capacity of the compressor, without the use of a bypass (e.g. recycle valve), shall be either the capacity at the anti-surge control line or 10 % greater than the predicted surge capacity shown in the proposal.

6.1.3 The vendor shall provide a capacity limit for centrifugal and axial compressors to avoid damaging blade stresses.

6.2 Materials

Materials shall be in accordance with 6.2 of Part 1.

NOTE Refer to Part 1 Annex F for typical materials.

6.3 Casings

6.3.1 General

Casings shall be in accordance with 6.3 of Part 1 and 6.3.2 through 6.5.3, as follows.

6.3.2 Pressure-containing Casings

6.3.2.1 [●] The purchaser will specify the relief valve set pressure.

6.3.2.1.1 The maximum allowable working pressure (MAWP) of the casing shall be at least equal to the specified relief valve set pressure.

6.3.2.1.2 When a relief valve set pressure is not specified, the MAWP shall be at least 125 % of the maximum specified discharge pressure (gauge).

6.3.2.1.3 Overpressure protection shall be furnished by the purchaser.

6.3.2.2 Casings designed for more than one maximum allowable pressure level (split pressure-level casings) are permitted only in process air service with an atmospheric pressure inlet.

6.3.2.2.1 Split pressure-level casings are not permitted in other services unless specifically approved by the purchaser.

6.3.2.2.2 If approved, the vendor shall define the physical limits and the MAWP of each section of the casing.

6.3.2.3 Casings shall be radially split when the partial pressure of hydrogen (at MAWP) exceeds 1380 kPa gauge (200 psi gauge).

6.3.2.4 The partial pressure of hydrogen shall be calculated by multiplying the highest specified mole (volume) percent of hydrogen by the MAWP.

6.3.2.5 Each axially split casing shall be designed to allow removal and replacement of its upper half without disturbing rotor-to-casing running clearances and bearing alignment.

6.3.2.6 Axially split casings shall use a metal-to-metal bolted joint with a suitable joint compound compatible with the process gas.

6.3.2.6.1 Gaskets (including string type) shall not be used on the axial joint.

6.3.2.6.2 O-rings retained in grooves machined into the flange facing of an axially split casing joint may be used with purchaser's approval.

6.3.2.7 Radially split casings that use O-rings, gaskets, or other sealing devices between the end head(s) and cylinder shall have these devices confined in machined grooves.

NOTE Refer to 6.2.1.16 of Part 1 for O-ring material selection and design considerations.

6.3.2.8 Socket-head or spanner-type bolting shall not be used externally unless specifically approved by the purchaser.

6.3.2.9 The main casing joint studs and nuts shall be designed for the use of hydraulic bolt tensioning. Procedures and extent of special tooling provided by the vendor shall be agreed.

6.3.3 Casing Repair

Casing repairs shall be in accordance with 6.3.2 of Part 1.

6.3.4 Material Inspection of Pressure-containing Parts

Casing material inspection of pressure-containing parts shall be in accordance with 6.3.3 of Part 1.

6.4 Pressure Casing Connections

6.4.1 Pressure casing connections shall be in accordance with 6.4 of Part 1 and the following paragraphs.

6.4.2 Main inlet and outlet connections for radially split machines shall be located in the outer casing, not in the end heads.

NOTE On radially split overhung design machines, the process inlet connection can be in the end head.

6.4.3 Auxiliary connections shall be at least DN 20 ($^3/_4$ in. nominal pipe size).

NOTE See 6.4.1.4 ,6.4.1.5 of Part 1 for allowable connection sizes.

6.4.4 Threaded connections for pipe sizes DN 20 (NPS $^3/_4$ in.) through DN 40 (NPS 1 $^1/_2$ in.) sizes are permissible with the approval of the purchaser.

NOTE See 6.4.1.4, 6.4.1.5 of Part 1 for allowable connection sizes.

6.4.5 [●] If specified, connections for borescopic examination shall be supplied in agreed locations.

6.5 Stationary Components

6.5.1 Casing Support Structures

Refer to 6.5.1 of Part 1 for casing support structure requirements.

6.5.2 External Forces and Moments

6.5.2.1 The compressor shall be designed to withstand external forces and moments on each nozzle calculated per Annex E.

6.5.2.2 The vendor shall furnish the allowable forces and moments for each nozzle in tabular form.

6.5.2.3 Casing and supports shall be designed to have sufficient strength and rigidity to limit coupling movement caused by imposing allowable forces and moments to 50 μm (0.002 in.).

6.5.3 Guide Vanes, Stators, and Stationary Internals

6.5.3.1 [●] If specified or required to meet specified operating conditions, variable inlet guide vanes (VIGVs) on centrifugal compressors shall be supplied.

6.5.3.2 [●] If specified or required to meet specified operating conditions, variable stators on axial compressors shall be supplied.

NOTE All or some of the stator blade rows can be adjustable.

6.5.3.3 Except for the machines handling air, the guide vane housing shall incorporate an external shell capable of providing an external purge of filtered air or inert gas.

6.5.3.4 A vane control system consisting of a positioner with direct driven local position indicator shall be provided that will be visible during operation of the machine.

6.5.3.5 Guide vanes shall be mounted in replaceable bushings.

6.5.3.6 Vanes may be positioned in the housing by replaceable permanently sealed rolling element bearings if approved by the purchaser.

6.5.3.7 If inlet guide vanes or variable stators are used for toxic, flammable, or explosive process gas, the linkage passing through the casing or enclosure shall be sealed to prevent leakage.

6.5.3.8 The vane position, on loss of the control signal, shall be agreed between the vendor and the purchaser. The final position of inlet guide vanes should not cause damage to the machine nor cause an internal stage surge event.

6.5.3.9 If intermediate main suction or discharge process connections are used, the purchaser shall specify the maximum differential pressure between the connections if intermediate check valves are used.

6.5.3.10 The vendor shall design the intermediate diaphragm between the process connections for the expected maximum differential.

6.5.3.11 The stationary guide vanes in an axial compressor shall be fully welded to create a completely sealed weld between the holder and the vanes.

6.5.4 Seal Components

Seal components shall be separate parts and be renewable or replaceable in order to restore design clearances.

6.5.5 Diaphragms

6.5.5.1 Diaphragms shall be axially split unless otherwise approved by the purchaser.

6.5.5.2 The diaphragms shall be furnished with threaded holes for eyebolts or with another means to facilitate removal.

6.5.5.3 The procedure to remove upper half diaphragms for axially split machine shall be agreed between the vendor and the purchaser.

6.5.5.4 The internals of radially split multistage compressors shall be designed with an inner barrel assembly for withdrawal from the outer casing and disassembly for inspection or replacement of parts.

6.5.5.5 The vendor shall advise if a cartridge bundle assembly can be provided.

NOTE This option can reduce maintenance time in the field.

6.6 Rotating Elements

6.6.1 General

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

6.6.1.2 Unless other shaft protection is approved by the purchaser, renewable components shall be furnished at interstage close-clearance points.

6.6.1.3 Shaft sleeves shall be provided under shaft end seals. Sleeves shall be treated to resist wear and sealed to prevent gas leakage between the shaft and sleeve.

6.6.1.4 Shaft sleeves shall be provided under interstage seals.

NOTE Closed impeller eye seals, which are stationary, do not require replaceable sleeves on the impeller.

6.6.2 Shafts

6.6.2.1 Shafts for non-through-bolt rotors shall be made of one-piece, heat-treated steel.

6.6.2.1.1 Shafts that have a finished diameter larger than 200 mm (8 in.) shall be forged steel.

6.6.2.1.2 Shafts that have a finished diameter of 200 mm (8 in.) or less shall be forged steel or hot rolled bar stock, providing such bar stock meets all quality and heat treatment criteria established for shaft forgings.

6.6.2.2 When modular (through bolt) rotors are provided, the stub shafts shall meet all quality and heat treatment criteria for shaft forgings.

NOTE Refer to Annex C for rotor arrangements and nomenclature.

6.6.2.2.1 The studs or tie-bolts used to clamp a built-up rotor shall be made from bar or forgings.

6.6.2.2.1.1 Threads shall be formed by rolling.

6.6.2.2.1.2 Each tie-bolt shall be tested with a proof load corresponding to at least 110 % of maximum stretch that occurs during assembly or in operation.

6.6.2.2.2 Ferromagnetic material shall be DC wet magnetic particle inspected.

6.6.2.2.2.1 Nonmagnetic material shall be fluorescent penetrant inspected.

6.6.2.2.2.2 These inspections shall be performed subsequent to proof-load test.

6.6.2.2.2.3 Inspections shall not reveal cracks, seams, or laps.

6.6.2.3 The acceptable methods of compressor rotor construction are solid (one-piece), disk-on-shaft, or stub shaft using through bolt and disk or drum construction. Any other rotor construction method has to be approved by the purchaser.

6.6.3 Thrust Balancing

6.6.3.1 A balance piston, balance line, and porting shall be provided if required to reduce axial loads on the thrust bearings.

6.6.3.2 A separate pressure-tap connection or connections shall be provided to indicate the pressure in the balancing chamber, not in the balance line.

6.6.3.3 The balance line, if required, shall be flanged and sized to handle balance piston gas leakage at twice the initial design balance piston seal clearance without exceeding the load rating of the thrust bearings. If the balance line involves a connection to purchaser's piping, then the connection size and locations should be indicated on the datasheets.

6.6.3.4 [●] If specified, a pressure tap connection shall be supplied in the downstream end of the balance line to allow measurement of differential pressure in the balance line.

NOTE This connection can be in the compressor supply or in the process piping.

6.6.3.5 [●] If specified, a differential pressure gage or transmitter shall be supplied to monitor differential balance line pressure.

6.6.4 Impellers

Refer to 6.6.2 of Part 1 for impeller requirements.

6.6.5 Axial Compressor Rotor Blading

6.6.5.1 The blade natural frequencies shall not coincide with any source of excitation from 10 % below minimum allowable speed to 10 % above maximum continuous speed (N_{mc}).

6.6.5.1.1 If this is not feasible, blading shall be designed with stress levels low enough to allow unrestricted operation, at any specified operating speed for the minimum service life defined in 6.1.3.3 of Part 1.

6.6.5.1.2 This shall be verified by Goodman diagrams or their equivalent.

6.6.5.1.3 The vendor shall identify unacceptable speeds.

6.6.5.1.4 Goodman diagrams for all blades shall be submitted to the purchaser for review.

NOTE Excitation sources include fundamental and first and second harmonic passing frequencies of rotating and stationary blades upstream and downstream of each blade row, gas passage splitters, irregularities in vane and periodic impulses caused by nozzle segment design at horizontal casing flanges, and the first 10 rotor speed harmonics.

6.6.5.2 For each blade row, the vendor shall present bending and torsional blade natural frequencies under both operating and static conditions by Campbell diagrams and their equivalent.

6.6.5.3 [●] If specified, or if blade natural frequencies are based on theoretical predictions, at least one blade from each stage shall be verified by ring testing.

6.6.5.4 All blades shall be shot peened unless this process introduces deficiencies in the blade material strength and/or hardness.

NOTE Peening intensity and media depend upon base material, compressive layer depth desired and material thickness.

6.6.5.5 The compressive layer induced shall be checked by using Almen strip.

6.6.5.6 Axial compressor rotor blading may be attached via axial dovetail, tangential fir tree, tangential, or T-slot. Other attachment methods are acceptable if approved by purchaser.

6.7 Bearings and Bearing Housings

6.7.1 General

Refer to 6.7 of Part 1 and the following sections for bearing and bearing housing requirements.

6.7.1.1 Hydrodynamic radial and thrust bearings shall be provided.

6.7.1.2 [●] If specified, active magnetic bearings (AMBs) shall be provided.

NOTE Annex D of Part 1 gives application considerations for use of AMBs.

6.7.1.3 Thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API 670.

6.7.1.4 As a design criterion, bearing metal temperatures shall not exceed 95 °C (200 °F) at specified operating conditions.

6.7.1.4.1 In the event that the above design criteria cannot be met, the purchaser and the vendor shall agree on acceptable bearing metal temperatures.

6.7.1.4.2 Vendors shall provide bearing temperature alarm and shutdown limits.

6.7.2 Hydrodynamic Radial Bearings

6.7.2.1 Hydrodynamic bearings shall have flood lubrication. Directed lube may be used if agreed.

6.7.2.2 Sleeve or pad radial bearings shall be used and shall be split for ease of assembly.

6.7.2.2.1 The use of nonsplit designs requires the purchaser’s approval.

6.7.2.2.2 The bearings shall be precision bored with steel or copper alloy backed babbitted replaceable liners, pads, or shells.

6.7.2.2.3 The bearing design shall not require removal of the coupling hub to permit replacement of the bearing liners, pads, or shells unless approved by the purchaser.

6.7.2.3 The removal of the top half of the casing of an axially split machine or the head of a radially split unit shall not be required for replacement of these elements.

NOTE This could not be possible for overhung designs.

6.7.3 Hydrodynamic Thrust Bearings

6.7.3.1 Thrust bearings shall be steel-backed, babbitted multiple segments designed for equal thrust capacity in both axial directions and arranged for continuous pressurized lubrication to each side.

6.7.3.2 Both sides shall be tilting pads, incorporating a self-leveling feature, which ensures that each pad carries an equal share of the thrust load even with minor variation in pad thickness.

NOTE Some low inlet pressure overhung compressors or axials will not need to meet the equal thrust load bidirectional criteria.

6.7.3.3 Each pad within one side of the thrust bearing shall be designed and manufactured to tolerances to allow interchange or replacement of the individual pads.

NOTE Instrumented and offset pivot designs do not allow interchange side to side.

6.7.3.4 Directed lube thrust bearings shall be used.

6.7.3.5 Flooded lube may be used with the purchaser’s approval.

6.7.3.6 [●] If specified or with the purchaser’s approval, thrust bearings pads shall be copper-alloy backed.

6.7.4 Bearing Housings

6.7.4.1 Rotor support system parts (bearings, bearing housings, bearing carriers, and bearing brackets) shall be separable from the casing, axially split, nonpressurized (vented to atmosphere), and furnished with plugged connections for dry air or inert gas purge to any atmospheric labyrinth seals.

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

6.7.4.3 Shaft support structures bolted to casings shall be steel.

6.7.4.4 Shaft support structures bolted to cast iron casings may be made from cast iron.

6.8 Dynamics

Refer to 6.8 of Part 1 for dynamics requirements.

6.9 Other Standard Specific Components

6.9.1 Shaft End Seals

6.9.1.1 Shaft end seals shall be in accordance with 6.9.1 of Part 1 and the following paragraphs.

6.9.1.2 [●] The purchaser shall specify the type of shaft end seal(s) to be provided and all operating conditions including start-up, shutdown, transient, and settle-out conditions.

NOTE Axial compressors in process air service will generally be supplied with labyrinth shaft end seals.

6.9.1.3 Shaft end seals and sleeves for noncartridge seal types (if not shrink fit) shall be accessible for inspection and replacement without removing the top half of the casing for an axially split compressor or the heads of a radially split unit.

NOTE 1 This requirement is not applicable for overhung designs.

NOTE 2 This is of benefit for seal types where the wearing component is in close proximity to the sleeve. Example seal types are labyrinth and carbon ring.

6.9.2 Integral Gearing

Integral gearing is not applicable for equipment covered in this part. For external gearing, refer to API 613.

6.9.3 Nameplates and Rotation Arrows

6.9.3.1 Nameplates and rotation arrows shall be in accordance with 6.9.3 of Part 1 and this section.

6.9.3.2 The following data shall be clearly stamped or engraved on the nameplate:

- vendor's name;
- serial number;
- size, type, and model;
- rated capacity;
- rated power;
- lateral critical speeds up to and including the next lateral above N_{mc};
- purchaser item number or other reference;
- MAWP;
- minimum and maximum allowable working temperature;
- minimum operating speed;
- N_{mc};
- trip speed;
- hydrostatic test pressure;
- maximum sealing pressure.

6.9.3.3 Rotation arrows shall be cast-in or attached permanently (not glued) to each major item of rotating equipment at a readily visible location.

7 Accessories

7.1 General

7.1.1 Accessories shall be in accordance with Section 7 of Part 1.

7.1.2 Lubrication and Sealing Systems

Lubrication and sealing systems shall be in accordance with 7.1 of Part 1.

7.2 Soleplates and Baseplates

Soleplate and baseplates shall be in conformance with 7.2.1 of Part 1.

7.3 Controls and Instrumentation

7.3.1 General

Controls and instrumentation shall be in conformance with 7.3 of Part 1.

7.3.2 Control Systems

7.3.2.1 Control systems, when supplied, shall be in accordance with 7.3.2 of Part 1 with the additions as noted below.

7.3.2.2 Axial compressor vendors shall supply a map of allowable operating range to permit the design of control logic to prevent operation in the region of choke (capacity limit) and therefore avoid potentially dangerous blade stresses.

NOTE Figure 1 and Figure 2 show typical performance maps for axial compressors.

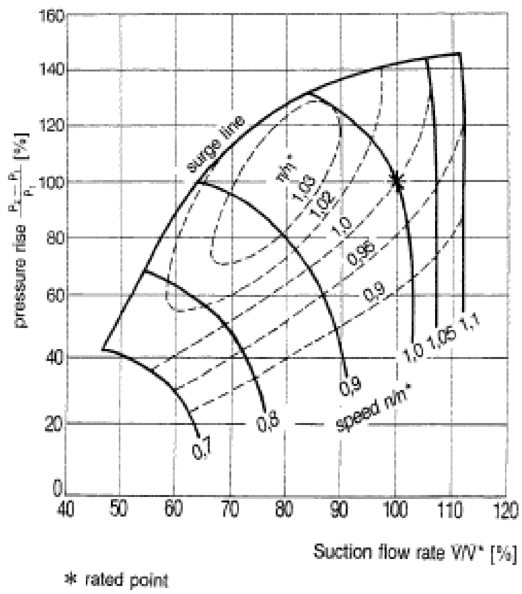


Figure 1—Axial Compressor Performance Map—Variable Speed

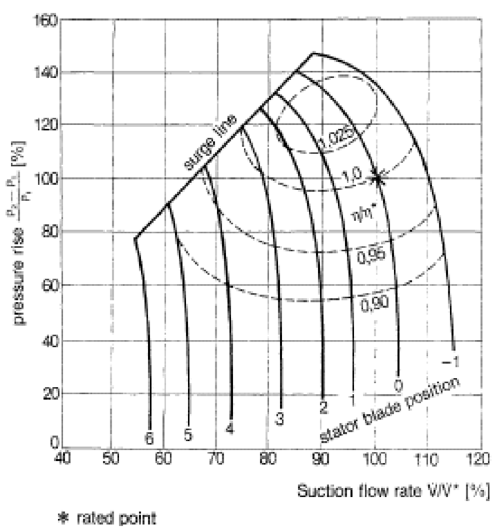


Figure 2—Axial Compressor Performance Map—Variable Stator Vanes

7.3.2.3 If an anti-surge control system as described in 7.3.2.2 and Annex E of Part 1 is furnished for an axial compressor, the system shall also include capacity limit protection.

7.3.2.4 For constant-speed centrifugal and axial compressors, when VIGVs are required, the vendor shall also furnish a guide vane positioner capable of supplying a compatible control signal as specified by the purchaser.

7.3.2.5 A direct driven local vane position indicator shall be provided that will be visible during operation of the machine.

NOTE See 7.3.2.1 of Part 1.

7.3.3 Instrument and Control Panels

Instrument and control panels, when supplied, shall be in accordance with 7.3.3 of Part 1.

7.3.4 Instrumentation

Instrumentation, when supplied, shall be in accordance with 7.3.4 of Part 1.

7.3.5 Alarms, Shutdowns, and Control Systems

Alarms, shutdowns, and control systems, when supplied, shall be in accordance with 7.3.5 of Part 1.

7.3.6 Electrical Systems

Electrical systems, when supplied, shall be in accordance with 7.3.6 of Part 1.

7.3.7 Vibration, Position, and Bearing Temperature Detectors

7.3.7.1 Radial shaft vibration and axial-position transducers and bearing temperature sensors shall be supplied, installed, and calibrated in accordance with API 670.

7.3.7.2 [●] If specified, radial shaft vibration and axial position monitors shall be supplied and calibrated in accordance with API 670.

7.3.7.3 [●] The purchaser shall specify the type of temperature detector to be supplied. Installation shall be per API 670.

7.3.7.4 [●] If specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API 670.

7.3.7.5 [●] If specified, casing vibration transducers shall be supplied, installed, and calibrated in accordance with API 670.

7.3.7.6 [●] If specified, casing vibration monitors shall be supplied, installed and calibrated in accordance with API 670.

7.4 Special Tools

Special tools shall be in accordance with 7.4 of Part 1.

7.5 Couplings and Guards

Couplings and guards shall be in conformance with 7.5 of Part 1.

7.6 Drivers and Gearing

Drivers and external gearing shall be in conformance with 7.6 of Part 1.

7.7 Enclosures and Insulation

(Intentionally Left Blank)

7.8 Other Standard Specific Systems

7.8.1 Piping and Appurtenances

7.8.1.1 General

Piping and appurtenances furnished shall be in accordance with 7.8.1 of Part 1, with additions as follows.

7.8.1.1.1 When a baseplate has been specified, the vendor shall furnish all piping systems, including mounted appurtenances, located within its confines.

7.8.1.1.1.1 The piping shall terminate with flanged connections at the edge of the baseplate.

7.8.1.1.1.2 When soleplates have been specified, the extent of the piping system supplied by the vendor shall be defined by the purchaser.

7.8.1.1.1.3 The purchaser will furnish interconnecting piping between equipment groupings and off base facilities.

7.8.1.1.2 [●] If specified, a liquid injection manifold shall be supplied including a throttle valve, an armored flow meter, a check valve, a pressure indicator, and a block valve for each injection point.

7.8.2 Process Piping

Process piping, if furnished, shall be in accordance with API 614.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

General requirements for inspection, testing, and preparation for shipment shall be in accordance with 8.1 of Part 1. Also refer to Annex D for the Inspector's Checklist.

8.2 Inspection

Requirements for inspection shall be in accordance with 8.2 of Part 1.

8.3 Testing

8.3.1 General

8.3.1.1 In addition to the requirements of 8.3 of Part 1, the compressor(s) shall be tested in accordance with 8.3.2 and 8.3.3.

8.3.1.2 Optional tests that may be specified are described in 8.3.4.

8.3.1.3 Immediately upon completion of each witnessed mechanical or performance test, copies of the data recorded during the test shall be given to the witnesses.

8.3.2 Mechanical Running Test

8.3.2.1 The requirements of 8.3.2.1.1 through 8.3.2.1.14 shall be met before the mechanical running test is performed.

8.3.2.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test, except that the atmospheric breakdown bushing(s) on oil seals may be replaced with a test bushing, if required.

NOTE Low-pressure mechanical testing can require increased clearance or fewer elements for proper heat removal.

8.3.2.1.2 Oil viscosity, pressures, and filtration shall be within the range of operating values recommended in the vendor's operating instructions for the unit being tested.

8.3.2.1.3 Oil flow rates to each oil seal and bearing housing shall be measured.

NOTE Oil inlet temperature can be varied for the mechanical test to match the design oil viscosity.

8.3.2.1.4 Oil system components downstream of the filters shall meet the cleanliness requirements of API 614, before any test is started.

8.3.2.1.5 Facilities that are to operate through the test shall be installed to prevent the entrance of oil into the process gas section of the compressor during the mechanical running test.

8.3.2.1.6 Testing with the contract coupling(s) is preferred. If this is not practical, the mechanical running test shall be performed with coupling(s) or simulators that have overhung moments within 10 % of the contract coupling(s).

8.3.2.1.7 The circumferential location of a hydraulically mounted coupling hub relative to the shaft shall be nonpermanently marked before starting the test.

8.3.2.1.8 The equipment shall be operated at speed increments of approximately 10 % from zero to the trip speed and run at the trip speed until bearing metal temperatures and shaft vibrations have stabilized [1 °C (2 °F) over 10 minutes] (see Figure 3).

NOTE 1 Operating equipment at or near critical speeds is normally avoided. For axial compressors, other speeds at or near blade resonant frequencies are also avoided (see 6.6.5.1).

NOTE 2 Refer to Figure 3 for a graphical illustration of the complete mechanical running test including requirements of 8.3.2.1.10 through 8.3.2.1.14.

NOTE 3 It can be required to ramp through certain speed ranges to avoid resonant frequencies.

8.3.2.1.9 The speed shall be held at trip speed for a minimum of 15 minutes.

8.3.2.1.10 The amplitudes and phase angle of the shaft vibration shall be recorded during a coast down from trip speed to slow roll.

8.3.2.1.11 A check of slow roll run out shall be performed and recorded.

8.3.2.1.12 The equipment shall be accelerated from slow roll to N_{mc}.

8.3.2.1.12.1 The equipment shall be run for 4 hours continuous operation.

8.3.2.1.12.2 After the 4-hour run at N_{mc}, the speed shall be increased to the trip speed.

8.3.2.1.12.3 The amplitudes and phase angle of the shaft vibration shall be recorded during coast down.

8.3.2.1.13 During the mechanical run test, the machine shall be driven from the same end as the field driver.

8.3.2.1.14 The impact on the mechanical run test, if driven from the other end than the field driver, shall be agreed between the vendor and the purchaser.

8.3.2.2 During the mechanical running test, the requirements of 8.3.2.2.1 through 8.3.2.2.10 shall be met.

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

8.3.2.2.1.1 The measured unfiltered vibration shall not exceed the limits of 6.8.9.1 of Part 1.

8.3.2.2.1.2 The measured unfiltered vibration shall be recorded throughout the operating speed range.

8.3.2.2.1.3 Any other test acceptance criteria shall be agreed and stated in the test agenda.

8.3.2.2.2 While the equipment is operating at N_{mc}, or other speed required by the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous.

8.3.2.2.2.1 These data shall cover a frequency range from 0.25 to 8 times the N_{mc}.

8.3.2.2.2.2 The amplitude of any discrete, nonsynchronous vibration shall not exceed 20 % of the allowable vibration as defined in 6.8.9.1 of Part 1.

8.3.2.2.3 During the mechanical running test, the highest bearing metal temperature shall not exceed 95 °C (200 °F) at N_{mc}.

8.3.2.2.4 The mechanical running test shall verify that lateral critical speeds conform to the requirements of 6.8.2.9 in Part 1 of this standard.

8.3.2.2.5 Shop verification of the unbalanced response analysis shall be performed in accordance with 6.8.3 in Part 1 of this standard.

8.3.2.2.6 If spare rotors are supplied to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with the requirements of this standard.

8.3.2.2.7 If spare inner barrel assemblies or cartridges bundle assemblies are supplied, the spare rotor shall be tested with the spare inner barrel assembly.

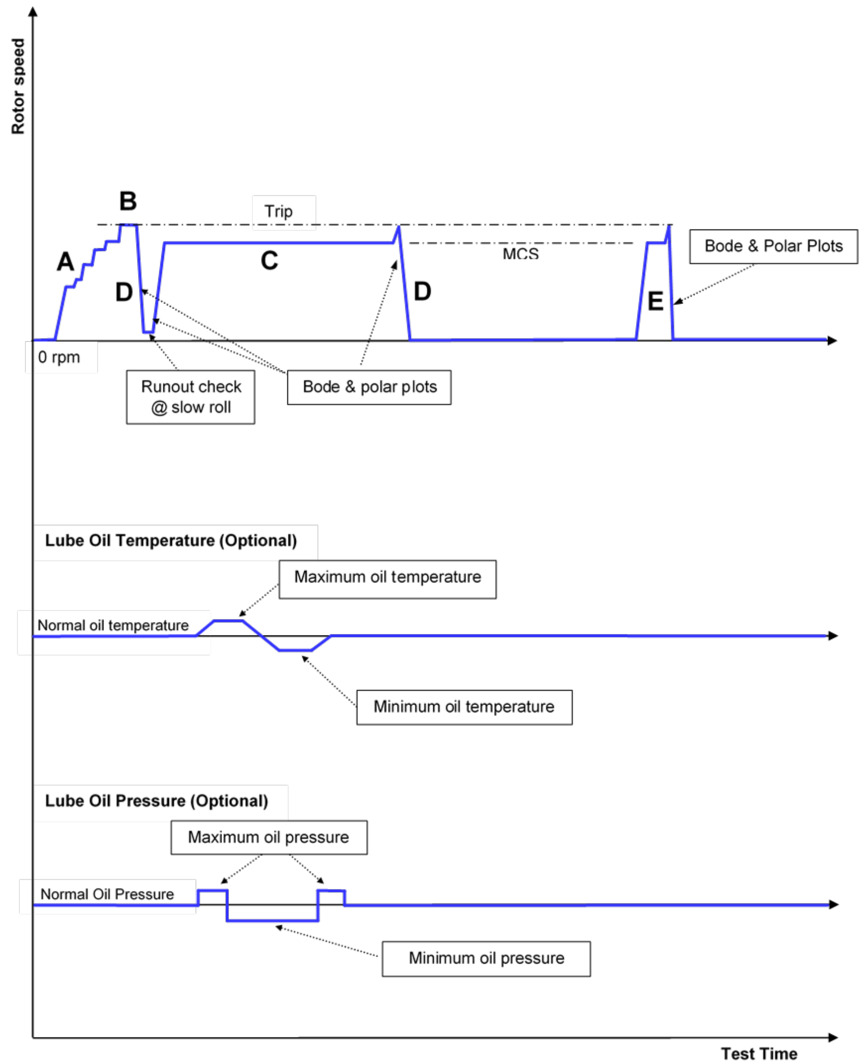
NOTE 1 Spare cartridge bundle assemblies can result in reduced turnaround time.

NOTE 2 See 3.1.7 and 3.1.19 of Part 1 for definitions of cartridge bundle assembly and inner barrel assembly, respectively.

8.3.2.2.8 If spare axial blade stator vane assemblies are supplied, the spare rotor shall be tested with the spare stator vanes.

8.3.2.2.9 The purchaser shall advise additional testing requirements for spare parts.

8.3.2.2.10 Axial compressors with variable stators shall be exercised throughout the entire range of movement using the contract linkage and linkage positioner during the mechanical test.



Key

A warm-up phase
- — speed increased multiple increments
- — avoid critical speeds, blade frequencies, etc.

B trip speed operation
- — 15 minutes

C maximum continuous speed 4-hour test
- — oil supply variations performed
- — operating conditions recorded

D shutdown/ramp down
- — momentary increase to trip speed
- — transient operation recorded
- — used as baseline for verification testing

E unbalance rotor response verification test (see 6.8.3 of Part 1)

Figure 3—Mechanical Running Test

8.3.3 Assembled Compressor Gas Leakage Test

8.3.3.1 After the mechanical running test is completed, each completely assembled compressor casing intended for toxic, hazardous, or flammable service shall be tested as required in 8.3.3.2 or, if specified, 8.3.3.3.

NOTE These tests are intended to verify the integrity of the casing joint. Some shaft seal designs are not gas tight. Therefore, leakage from these seals is acceptable.

8.3.3.2 The assembled compressor (including end seals) shall be pressurized, with an inert gas to the maximum sealing pressure or the maximum seal design pressure, as agreed by the purchaser and the vendor.

8.3.3.2.1 This shall be held at no less than this pressure for a minimum of 30 minutes and subjected to a soap bubble test, or alternate method, to check for gas leaks.

8.3.3.2.2 The test shall be considered satisfactory when no casing or casing joint leaks are observed.

NOTE Test gas mole weight approximates or is less than contract gas mole weight. Helium for low mole weight contract gas and nitrogen or refrigerant gas for high mole weight can be considered.

8.3.3.3 [●] If specified, the assembled compressor (with or without end seals installed) shall be pressurized with an inert gas to the maximum specified discharge pressure, held at this pressure for a minimum of 30 minutes, and subjected to a soap bubble test, or alternate method, to check for gas leaks and considered satisfactory when no casing or casing joint leaks are observed.

8.3.4 Optional Tests

8.3.4.1 The purchaser will specify whether the shop tests specified in 8.3.5 through 8.3.5.8 shall be performed.

8.3.4.2 Test details shall be agreed prior to the test.

8.3.5 Factory Performance Test

8.3.5.1 The performance test shall be performed in accordance with ASME PTC 10. If specified, ISO 5389 shall be used.

8.3.5.2 A minimum of five points, including surge and overload, shall be taken at the speed and inlet guide vane setting (if applicable) equivalent to normal speed.

NOTE Refer to the applicable test code for general instructions. ASME PTC 10 cannot apply to some low-pressure ratio compressors. Refer to the scope of ASME PTC 10 for the selection of the appropriate test code to be used.

8.3.5.3 [●] If specified, surge line testing or additional speed lines may be tested for variable-speed machines or additional guide vane angles for machines with VIGVs.

8.3.5.4 For variable-speed machines, head shall have zero negative tolerance at the certified point capacity, and the power at this point shall not exceed 104 % of the vendor predicted shaft power value. This tolerance shall be inclusive of all test tolerances. Surge shall comply with provisions of 6.1.2.

NOTE Both of the performance test codes referred to have provision for calculating inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore, are not to be further additive.

8.3.5.5 For variable-speed compressors, a speed other than the normal speed may be used, if necessary, to achieve the specified conditions, provided that this adjusted speed meets the criteria specified in 6.8 of Part 1.

8.3.5.6 Variable-speed compressors shall have N_{mc} increased, if necessary, after performance testing to maintain a minimum 5 % margin over adjusted rated speed based on test.

8.3.5.7 If a speed increase is necessary to achieve specified performance, all design margins such as separation margins, overspeed margins, maximum continuous margins, etc. shall meet requirements.

NOTE This maintains a 5 % speed margin for future process changes.

8.3.5.8 For constant-speed driven compressors, the capacity shall have zero negative tolerance at the certified point.

8.3.5.8.1 The head shall be within the range of 100 % to 105 % of the normal head.

8.3.5.8.2 The horsepower, based on measured head at certified capacity, shall not exceed 107 % of the value at the specified certified point.

8.3.5.8.3 If the power required at this point exceeds 107 %, or head exceeds 105 % of the normal head, excess head may be removed by trimming impellers at the purchaser's option.

8.3.5.9 If hardware modifications are required to meet performance, the performance test shall be repeated.

8.3.5.10 The performance test shall be conducted using only one contract rotor.

8.3.5.11 [●] If specified, the purchaser shall state the intermediate pressures.

8.3.5.12 Manufacturer shall state the pressure tolerance at each connection.

8.3.5.13 For trains with multiple compressors, intermediate pressures and individual power tolerances may be adjusted as agreed. Overall power tolerances shall be as stated above.

8.3.6 Complete Unit Test

8.3.6.1 [●] If specified, a complete unit test shall be performed. The scope of this test shall be detailed by the purchaser.

8.3.6.1.1 Such components as compressors, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test.

8.3.6.1.2 A separate auxiliary test may be performed.

8.3.6.1.3 The complete unit test may be performed in place of, or in addition to, separate tests of individual components.

8.3.6.2 [●] If specified for the complete unit test, torsional vibration measurements shall be made to verify the vendor's analysis.

8.3.7 Tandem Test

[●] If specified, compressor bodies arranged for tandem drive shall be tested as a unit during the mechanical running test, using the shop driver and oil systems as specified.

8.3.8 Gear Test

[●] If specified, for units with external gears, the contract gear shall be tested with the machine(s) during the mechanical running test.

8.4 Preparation for Shipment

8.4.1 Equipment shall be prepared for shipment in accordance with 8.4 of Part 1.

8.4.2 [●] If specified, dry gas seals shall be removed for shipment.

NOTE Seals will have to be reinstalled in the field or cover plates fabricated if the compressor is to be provided with a nitrogen blanket during construction.

9 Vendor's Data

9.1 General

9.1.1 Vendor's data shall be in accordance with Section 9 of Part 1.

9.1.2 [●] If specified, the information to be furnished by the vendor is specified in Annex B and Part 1 Annex I and supplied per 9.1.2.1 and 9.1.2.2.

9.1.2.1 The vendor shall complete and forward the agreed vendor drawing and data requirements (VDDR) Form (see Annex B) to the address or addresses noted on the inquiry or order.

9.1.2.2 This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

9.2 Proposals

Proposal data shall be in accordance with I.2 of Part 1.

9.3 Contract Data

Contract data shall be in accordance with I.3 of Part 1.

Annex A
(normative)

Datasheets

A representation of the datasheets is enclosed in this annex; however, MS Excel format datasheets have been developed and are available, for purchase from API publications distributors, with this standard. The MS Excel electronic datasheets can have additional functionality over printed hard copies.

	REVISION	0	1	2	3	4
	DATE					
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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2) SI UNITS (bar)	REV/APPR					
	JOB NO.			ITEM NO.		
	PAGE	1	OF 12	REQ'N NO.		

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

FOR ______ UNIT ______

SITE ______ SERIAL NO. ______

SERVICE ______ NO. REQUIRED ______

MANUFACTURER ______ DRIVER TYPE ______

MODEL ______ DRIVER ITEM NO. ______

APPLICABLE STANDARD: ○ US ○ ISO

INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)	NORMAL	OTHER CONDITIONS A	B	C	D	E
○ GAS HANDLED (ALSO SEE PAGE ____)						
△ GAS PROPERTIES						
○ STANDARD VOLUME FLOW (M^3/H - 1.013 barA & 0°C DRY)						
○ WEIGHT FLOW (kg/h) (WET) (DRY)						
INLET CONDITIONS						
○ PRESSURE (barA)						
○ TEMPERATURE (°C)						
○ RELATIVE HUMIDITY %						
○ MOLECULAR WEIGHT						
□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
□ INLET VOLUME (m^3/h) (WET / DRY)						
DISCHARGE CONDITIONS						
○ PRESSURE (barA)						
□ TEMPERATURE (°C)						
□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
□ GAS POWER REQUIRED (kW)						
□ TRAIN POWER REQUIRED (kW)						
□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (kW)						
□ SPEED (rpm)						
□ TURNDOWN (%)						
□ POLYTROPIC HEAD (N-m/kg)						
□ POLYTROPIC EFFICIENCY (%)						
○ CERTIFIED POINT						
□ PERFORMANCE CURVE NUMBER						

PROCESS CONTROL

METHOD ○ SUCTION THROTTLING FROM ______ (barA) TO ______ (barA) ○ VARIABLE INLET GUIDE VANES ○ SPEED VARIATION FROM ______ % TO ______ % ○ DISCHARGE BLOWOFF TO ______ ○ COOLED BYPASS FROM ______ TO ______

SIGNAL ○ SOURCE ______

TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______

RANGE ______ (mA) ______ (barG) ______

START-UP ○ FROM SETTLE OUT CONDITION ○ NORMAL SUCTION PRESSURE ○ OTHER: ______

REMARKS: NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

			0	1	2	3	4

CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 2 OF 12 REQ'N NO. ______

		NORMAL	A	B	C	D	E
1	**OPERATING CONDITIONS**						
2		**NORMAL**	**OTHER CONDITIONS**				
3	(ALL DATA ON PER UNIT BASIS)		**A**	**B**	**C**	**D**	**E**
4							
5	○ GAS HANDLED (ALSO SEE PAGE ____)						
6	△ GAS PROPERTIES						
7	○ STANDARD VOLUME FLOW (M^3/H - 1.013 barA & 0°C DRY)						
8	○ WEIGHT FLOW (kg/h) (WET) (DRY)						
9	**INLET CONDITIONS**						
10	○ PRESSURE (barA)						
11	○ TEMPERATURE (°C)						
12	○ RELATIVE HUMIDITY %						
13	○ MOLECULAR WEIGHT						
14	☐ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
15	☐ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
16	☐ INLET VOLUME (m^3/h) (WET / DRY)						
17	**DISCHARGE CONDITIONS**						
18	○ PRESSURE (barA)						
19	☐ TEMPERATURE (°C)						
20	☐ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
21	☐ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
22	☐ GAS POWER REQUIRED (kW)						
23	☐ TRAIN POWER REQUIRED (kW)						
24	☐ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (kW)						
25	☐ SPEED (rpm)						
26	☐ TURNDOWN (%)						
27	☐ POLYTROPIC HEAD (N-m/kg)						
28	☐ POLYTROPIC EFFICIENCY (%)						
29	○ CERTIFIED POINT						
30	☐ PERFORMANCE CURVE NUMBER						
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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 3 OF 12 REQ'N NO. ______

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)	NORMAL	OTHER CONDITIONS A	B	C	D	E
○ GAS HANDLED (ALSO SEE PAGE ____)						
△ GAS PROPERTIES						
○ STANDARD VOLUME FLOW (M^3/H - 1.013 barA & 0°C DRY)						
○ WEIGHT FLOW (kg/h) (WET) (DRY)						
INLET CONDITIONS						
○ PRESSURE (barA)						
○ TEMPERATURE (°C)						
○ RELATIVE HUMIDITY %						
○ MOLECULAR WEIGHT						
□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
□ INLET VOLUME (m^3/h) (WET / DRY)						
DISCHARGE CONDITIONS						
○ PRESSURE (barA)						
□ TEMPERATURE (°C)						
□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
□ GAS POWER REQUIRED (kW)						
□ TRAIN POWER REQUIRED (kW)						
□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (kW)						
□ SPEED (rpm)						
□ TURNDOWN (%)						
□ POLYTROPIC HEAD (N-m/kg)						
□ POLYTROPIC EFFICIENCY (%)						
○ CERTIFIED POINT						
□ PERFORMANCE CURVE NUMBER						

REMARKS: NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

	REVISION	0	1	2	3	4
	DATE					

CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 4 OF 12 REQ'N NO. ______

OPERATING CONDITIONS (Continued)

GAS ANALYSIS:		NORMAL	OTHER CONDITIONS					REMARKS:
○ MOL %			A	B	C	D	E	
	MW							
AIR	28.966							
OXYGEN	32.000							
NITROGEN	28.016							
WATER VAPOR	18.016							
CARBON MONOXIDE	28.010							
CARBON DIOXIDE	44.010							
HYDROGEN SULFIDE	34.076							
HYDROGEN	2.016							
METHANE	16.042							
ETHYLENE	28.052							
ETHANE	30.068							
PROPYLENE	42.078							
PROPANE	44.094							
I-BUTANE	58.120							
n-BUTANE	58.120							
I-PENTANE	72.146							
n-PENTANE	72.146							
CORROSIVE AGENTS								
TOTAL								
AVG. MOL. WT.								

LOCATION:
○ INDOOR ○ OUTDOOR ○ GRADE
○ HEATED ○ UNDER ROOF ○ MEZZANINE
○ UNHEATED ○ PARTIAL SIDES ○ ______

SITE DATA
○ ELEVATION ______ (m) BAROMETER ______ (barA)
○ RANGE OF AMBIENT TEMPS:

		DRY BULB	WET BULB
NORMAL	(°C)	______	______
MAXIMUM	(°C)	______	______
MINIMUM	(°C)	______	______
______	(°C)	______	______

UNUSUAL CONDITIONS: ○ DUST ○ FUMES
______ ______ ______
○ OTHER ______
______
○ COPPER AND COPPER ALLOYS PROHIBITED

COATING:
○ ROTATING COMPONENTS ______
○ STATIONARY COMPONENTS ______

REMARKS: ______

NOISE SPECIFICATIONS:
○ APPLICABLE TO MACHINE:
SEE SPECIFICATION ______
○ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION ______
ACOUSTIC HOUSING: ○ YES ○ NO

APPLICABLE SPECIFICATIONS:
API 617-9th, Part 2
○ VENDOR HAVING UNIT RESPONSIBILITY
______
○ GOVERNING SPECIFICATION (IF DIFFERENT)
______

○ ELEC. AREA CLASS. ○ NEC ○ IEC
EQUIPMENT
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______
CONTROL PANNELS
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______

○ INSTRUMENT AND CONTROLS
STANDARD ○ NEMA ○ IEC

	INDOOR	OUTDOOR
CONTROL ENCLOSURE	______	______
TERMINAL BOX	______	______

REVISION	0	1	2	3	4
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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ________ ITEM NO. ________
PAGE 5 OF 12 REQ'N NO. ________

1	**CONSTRUCTION FEATURES**	
2	☐ **SPEEDS:**	○ **INTERMEDIATE MAIN PROCESS CONNECTIONS**
3	MAX. CONT. ____ (rpm) TRIP ____ (rpm)	DISCH. PRESSURE: (barG) MAX ____ MIN ____
4	MAX. TIP SPEEDS: ____ (m/s) @ 100% SPEED	INLET PRESSURE: (barG) MAX ____ MIN ____
5	____ (m/s) @ MAX. CONT. SPEED	☐ **GUIDE VANES**
6	☐ **LATERAL CRITICAL SPEEDS (DAMPED)**	○ IGV EXTERNAL PURGE ____
7	FIRST CRITICAL ____ (rpm) ____ MODE	○ VANE CONTROL SYSTEM ____
8	SECOND CRITICAL ____ (rpm) ____ MODE	NUMBER OF AXIAL BLADE ROWS ____
9	THIRD CRITICAL ____ (rpm) ____ MODE	NUMBER OF ADJUSTIBLE ROWS ____
10	FOURTH CRITICAL ____ (rpm) ____ MODE	NO. VANES GUIDE VANE ____ MATERIAL ____
11	○ LATERAL ANALYSIS ADDITIONAL REQUIREMENTS	☐ **IMPELLERS:**
12	○ TRAIN LATERAL ANALYSIS REQUIRED	NO. ____ DIAMETERS ____
13	○ TORSIONAL ANALYSIS REQUIRED	NO. VANES EA. IMPELLER ____
14	☐ **TORSIONAL CRITICAL SPEEDS:**	TYPE (OPEN, ENCLOSED, ETC.) ____
15	FIRST CRITICAL ____ (rpm)	TYPE FABRICATION ____ MATERIAL ____
16	SECOND CRITICAL ____ (rpm)	MIN. YIELD STRENGTH (MPa) ____
17	THIRD CRITICAL ____ (rpm)	HARDNESS: (Rc) (BRINNEL) MAX ____ MIN ____
18	FOURTH CRITICAL ____ (rpm)	SMALLEST TIP INTERNAL WIDTH (mm) ____
19	○ LIST OF TRAIN UNDESIRABLE SPEEDS	MAX. MACH. NO. @ IMPELLER EYE ____
20	○ STABILITY ANALYSIS	MAX. IMPELLER HEAD @ 100% SPD (N-m/kg) ____
21	☐ **VIBRATION:**	☐ **SHAFT:**
22	ALLOWABLE RADIAL TEST LEVEL (P-P) ____ (µm)	○ ONE PIECE ○ BUILT UP
23	ALLOWABLE AXIAL TEST LEVEL (P-P) ____ (µm)	MATERIAL ____
24	**NAMEPLATE**	DIA @ IMPELLERS (mm) ____ DIA @ COUPLING (mm) ____
25	○ US CUSTOMARY ○ METRIC	SHAFT END: ○ TAPERED ○ CYLINDRICAL
26	☐ **ROTATION, VIEWED FROM DRIVEN END** ○ **CW** ○ **CCW**	○ SPLINED ○ INTEGRAL FLANGE
27	○ **MATERIALS INSPECTION REQUIREMENTS**	MIN. YIELD STRENGTH (MPa) ____
28	○ RADIOGRAPHY REQUIRED FOR ____	SHAFT HARDNESS (BNH)(Rc) ____
29	○ ULTRASONIC REQUIRED FOR ____	MAX TORQUE CAPABILITY (N-m) ____
30	○ MAGNETIC PARTICLE REQUIRED FOR ____	☐ **BALANCE PISTON:**
31	○ LIQUID PENETRANT REQUIRED FOR ____	MATERIAL ____ AREA ____ (mm²)
32	○ LOW TEMPERATURE ____	FIXATION METHOD ____
33	MIN. DESIGN METAL TEMPERATURE (°C) ____	NORMAL CLEARANCE (mm) ____
34	AT CONCURRENT PRESSURE (barG) ____	FLOW WITH NORMAL CLEARANCE (kg/h) ____
35	○ OTHER TRAIN COMPONENTS	FLOW WITH 2x NORMAL CLEARANCE (kg/h) ____
36	☐ **CASING:**	○ PRESS. CONN. BAL LINE DOWNSTREAM ○ GAUGE ○ TRANSMITTER
37	MODEL ____	☐ **SHAFT SLEEVES:**
38	CASING SPLIT ____	AT INTERSTG. CLOSE MATL ____
39	MATERIAL ____	CLEARANCE POINTS
40	THICKNESS (mm) ____ CORR. ALLOW. (mm) ____	AT SHAFT SEALS MATL ____
41	MAX. ALLOWABLE PRESS ____ (barG)	○ ACCESSIBLE
42	TEST PRESS: (barG) HELIUM ____ HYDRO ____	**ROTOR**
43	MAX. ALLOWABLE TEMPERATURE ____ (°C)	○ ____
44	MAX OPER. TEMP. ____ (°C) MIN. OPER. TEMP. ____ (°C)	○ AT SPEED BALANCING
45	MAX CASING CAPACITY ____ (m³/h)	○ SEQUENTIAL LOW SPEED BAL. PREC. AT SPEED BAL.
46	○ SYSTEM RELIEF VALVE SET PT. ____ (barG)	○ RESIDUAL UNBALANCE CHECK
47	○ Q.C. OF INACCESSIBLE WELDS	☐ **LABYRINTHS:**
48	☐ **DIAPHRAGMS:**	INTERSTAGE
49	MATERIAL ____	TYPE ____ MATERIAL ____
50	AXIALLY SPLIT ☐ YES ☐ NO	BALANCE PISTON
51	DIAPHRAGM MAX. ∆ P (BAR)(kPa):	TYPE ____ MATERIAL ____
52	**REMARKS:** ____	
53	____	
54	____	
55	____	
56	____	

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CENTRIFUGAL AND AXIAL COMPRESSOR
DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 6 OF 12 REQ'N NO. ______

LOW-PRESSURE CASING CONSTRUCTION FEATURES (CONTINUED)

SHAFT SEALS:
- ○ SEAL TYPE ______
- ○ SETTLE OUT PRESSURE (barG) ______
- ○ MIN.SEALING PRESSURE (barG) ______
- ○ SUPPLEMENTAL DEVICE REQUIRED FOR CONTACT SEALS TYPE ______
- ○ BUFFER GAS SYSTEM REQUIRED
- ○ TYPE BUFFER GAS ______
  - ☐ PRESSURE ______ (barG)
  - ☐ FLOW RATE ______ (kg/h)
  - ☐ FILTRATION ______ (µm)
- ○ MANIFOLD
- ○ METHOD OF CONTROL

- ○ BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR
- ○ PRESSURIZING GAS FOR SUBATMOSPHERIC SEALS
  - ○ EDUCTOR ○ INJECTION
- ☐ SEAL MANUFACTURER

FOR COMPLETE INFORMATION, SEE API 692 DATASHEET

BEARING HOUSING

☐ **BEARING HOUSING CONSTRUCTION:**

TYPE (SEPARATE, INTEGRAL) ______ SPLIT ______

MATERIAL ______

AXIAL COMPRESSOR

STAGE	1	2	3	4	5	6	7	8	9
ROTOR									
☐ BLADE MATERIAL									
☐ BLADE ROOT TYPE									
☐ CORD WIDTH (mm)									
☐ OUTER DIAMETER (mm)									
☐ BLADE HEIGHT (mm)									
☐ BLADE QUANTITY									
STATOR									
☐ BLADE MATERIAL									
☐ TYPE (FIXED, VARIABLE)									
☐ CORD WIDTH (mm)									
☐ BLADE QUANTITY									

STAGE	10	11	12	13	14	15	16	17	18
ROTOR									
☐ BLADE MATERIAL									
☐ BLADE ROOT TYPE									
☐ CORD WIDTH (mm)									
☐ OUTER DIAMETER (mm)									
☐ BLADE HEIGHT (mm)									
☐ BLADE QUANTITY									
STATOR									
☐ BLADE MATERIAL									
☐ TYPE (FIXED, VARIABLE)									
☐ CORD WIDTH (mm)									
☐ BLADE QUANTITY									

REMARKS:

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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 7 OF 12 REQ'N NO. ______

1	**CONSTRUCTION FEATURES (CONTINUED)**	
2	**BEARINGS AND BEARING HOUSINGS**	
3	○ ACTIVE MAGNETIC BEARINGS	
4	**RADIAL** — **THRUST** / **NON-THRUST**	**THRUST** — **ACTIVE** / **INACTIVE**
5	☐ TYPE	☐ TYPE
6	☐ MANUFACTURER	☐ MANUFACTURER
7	☐ LENGTH (mm)	☐ UNIT LOADING - MAX (bar)
8	☐ SHAFT DIA. (mm)	☐ UNIT LOAD - ULT. (bar)
9	☐ UNIT LOAD (ACT/ALLOW) (bar)	☐ AREA (mm²)
10	☐ BASE MATERIAL	☐ NO. PADS
11	☐ NO. PADS	☐ PIVOT: CENTER / OFFSET, %
12	☐ LOAD: B'TWN/ON PAD	☐
13	☐ PIVOT: CTR/OFFSET, %	PAD MATERIAL ○ STEEL BACKED ○ COPPER BACKED
14	☐	LUBRICATION: ○ FLOODED ○ DIRECTED
15	PAD MATERIAL ○ STEEL BACKED ○ COPPER BACKED	THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE
16	☐ BEARING SPAN ______ (mm)	MATERIAL ______
17		☐ SIZING CRITERIUM
18	**BEARING TEMPERATURE DETECTORS**	**VIBRATION DETECTORS:** ○ SEE ATTACHED API 670 DATASHEET
19	○ SEE ATTACHED API-670 DATASHEET	○ TYPE ______ ☐ MODEL ______
20	○ THERMOCOUPLES TYPE ______	○ MFR ______
21	○ RESISTANCE TEMP DETECTORS	○ NO. AT EA SHAFT BEARING ______ TOTAL NO. ______
22	○ RESISTANCE MAT'L ______ ○ ______ (OHMS)	○ OSCILLATOR-DETECTORS SUPPLIED BY ______
23	☐ ALARM TEMPERATURE ______ (°C)	○ MFR ______ ☐ MODEL ______
24	☐ SHUTDOWN TEMPERATURE ______ (°C)	MONITOR SUPPLIED BY ______
25	○ PROVISION FOR LOCAL DISCONNECT	○ LOCATION ______ ENCLOSURE ______
26	○ LOCATION-JOURNAL BRG	○ MFR. ______ ☐ MODEL ______
27	NO. ____ EA PAD ______ EVERY OTH PAD ____ PER BRG	☐ SCALE RGE ____ ○ ALARM ☐ SET @ ____ (µm)
28	OTHER ______	○ SHTDWN: ☐ SET @ ____ (µm) ○ TIME DELAY ____ (sec)
29	○ LOCATION-THRUST BRG	○ CASING VIBRATION TRANSDUCERS
30	NO. ____ EA PAD ______ EVERY OTH PAD ____ PER BRG	○ CASING VIBRATION MONITORS
31	OTHER ______	**AXIAL POSITION / VIBRATION DETECTOR** ○ SEE ATTACH. API-670
32	NO. (INACT) ____ EA PAD ____ EVERY OTH PAD ____ PER BRG	DATASHEET
33	OTHER ______	○ TYPE ______ ☐ MODEL ______
34	○ LOCAL DISCONNECTION	● MFR ______ ○ NO. REQUIRED ______
35	○ MONITOR SUPPLIED BY ______	○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
36	○ LOCATION ______ ENCLOSURE ______	○ MFR ______ ☐ MODEL ______
37	○ MFR. ______ ☐ MODEL ______	○ MONITOR SUPPLIED BY ______
38	☐ SCALE RGE ______ ○ ALARM ☐ SET @ ______ (°C)	○ LOCATION ______ ENCLOSURE ______
39	○ SHTDWN ☐ SET @ ____ (°C) ○ TIME DELAY ____ (sec)	○ MFR. ______ ☐ MODEL ______
40		☐ SCALE RGE ____ ○ ALARM ☐ SET @ ____ (µm)
41	**KEY PHASOR REQUIRED**	○ SHTDWN: ☐ SET @ ____ (µm) ○ TIME DELAY ____ (sec)
42	○ COMPRESSOR ○ GEAR H.S. ○ GEAR L.S.	
43	**CASING CONNECTIONS**	

Line	CONNECTION	☐ ANSI/ASME (B16.1; B16.5; B16.42; B16.47 series A, B; EN 1092-1 OR -2; OTHER)	☐ FACING ☐ BORE	○ ORIENTATION	○ FLANGED OR STUDDED	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY (m/s)
44–49							
50	INLET						
51	DISCHARGE						
52							
53							
54							

55 ○ BORESCOPIC INSPECTION PORTS

56

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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
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☐ **OTHER CONNECTIONS**

SERVICE:	NO.	SIZE	TYPE		NO.	SIZE	TYPE
LUBE-OIL INLET				PRESSURE			
LUBE OIL OUTLET				TEMPERATURE			
SEAL-OIL INLET				SOLVENT INJECTION			
SEAL-OIL OUTLET				PURGE FOR:			
SEAL GAS INLET				BRG. HOUSING			
SEAL GAS OUTLET				BTWN BRG & SEAL			
CASING DRAINS				BTWN SEAL & GAS			
STAGE DRAINS				______			

○ INDIVIDUAL STAGE DRAINS REQUIRED
○ VALVED & BLINDED
○ VALVED & BLINDED & MANIFOLD

LUBRICATION AND SEALING SYSTEMS

○ SEE ATTACHED API 614 DATASHEET
○ SEPARATE ○ COMBINED
○ INTEGRAL OIL RESERVOIR
△ OIL TYPE

ACCESSORIES

COUPLING AND GUARDS
NOTE: SEE ROTATING ELEMENTS - SHAFT ENDS
○ SEE ATTACHED API 671 DATASHEET ○ KEYLESS HYDRAULIC ○ KEYED ○ FLANGED ○ OTHER ______
COUPLING FURNISHED BY ______ MOUNTED BY ______
MANUFACTURER ______ TYPE ______ MODEL ______
COUPLING GUARD FURNISHED BY: ______
TYPE: ○ FULLY ENCLOSED ○ SEMI-OPEN ○ OTHER

COUPLING DETAILS
☐ MAX O.D. ______ (mm)
☐ HUB WEIGHT ______ (kg)
☐ SPACER LENGTH ______ (mm)
☐ SPACER WEIGHT ______ (kg)
○ PLUG AND RING GAUGES ○ LAPPING TOOL
COOLING REQUIREMENTS:
☐ FLOW RATE ______ (L/min)

MOUNTING PLATES
○ BASEPLATES FURNISHED BY ______
○ COMPRESSOR ONLY ○ DRIVER ○ GEAR
○ OTHER ______
○ NONSKID DECKING ○ SLOPED DECK
△ LEVELING PADS OR TARGETS
△ COLUMN MOUNTING
○ SUB-SOLE PLATES REQUIRED
☐ SHIM THICKNESS ______ (mm)
○ MACHINED MOUNTING PADS REQUIRED

○ SOLEPLATES FURNISHED BY ______
☐ THICKNESS ______ (mm)
○ ______
○ EXTENT OF PIPING ______
☐ SHIM THICKNESS ______ (mm)
○ COUNTER BORE ANCHOR BOLT HOLES

ANTI-SURGE SYSTEM FURNISHED BY ○ PURCHASER ☐ VENDOR
○ ☐ ANTI-SURGE VALVE ○ SIZING ONLY
PRESSURE UPSTREAM: ______ (barG) DOWNSTREAM ______ (barG)
☐ ∆ P VALVE ______ (bar) STROKE TIME OPEN - CLOSE ______ (sec)
○ ☐ RECIRCULATION VALVE ○ SIZING ONLY
○ ☐ BLOWOFF VALVE ○ SIZING ONLY
○ ☐ CONTROL SYSTEM
○ ☐ PIPING
○ ☐ FLOW ELEMENT
○ ☐ ______ ○ ☐ ______
○ ☐ ______ ○ ☐ ______
○ ☐ ______ ○ ☐ ______
○ ☐ ______ ○ ☐ ______
○ ☐ ______ ○ ☐ ______
○ ☐ ______ ○ ☐ ______

REMARKS: ______

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CENTRIFUGAL AND AXIAL COMPRESSOR
DATASHEET (API 617-9th, Part 2)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
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UTILITIES

○ **UTILITY CONDITIONS:**

STEAM: **DRIVERS**

	DRIVERS			
INLET MIN		(barG)		(°C)
NORM		(barG)		(°C)
MAX		(barG)		(°C)
EXHAUST. MIN		(barG)		(°C)
NORM		(barG)		(°C)
MAX		(barG)		(°C)

ELECTRICITY:

	DRIVERS	CONTROL	SHUTDOWN
VOLTAGE			
HERTZ			
PHASE			

○ REDUCED VOLTAGE START
△ NUMBER OF STARTS ______

INSTRUMENT AIR:
MAX PRESS ______ (barG) MIN PRESS ______ (barG)

SHOP INSPECTION AND TESTS

○ (SEE INSPECTOR'S CHECKLIST)	REQ'D	WIT/OBV
HYDROSTATIC	●	
IMPELLER OVERSPEED	●	
MECHANICAL RUN	●	
○ CONTRACT COUPLING ○ IDLING ADAPTOR(S)		
○ CONTRACT PROBES ○ SHOP PROBES		
○ PURCHASER VIB. EQUIPMENT		
VARY LUBE OIL PRESSURES AND TEMPERATURES	○	
UNBALANCE VERIFICATION TEST	○	
POLAR FORM VIB DATA	○	
RECORD VIB DATA	○	
SHAFT END SEAL INSP	○	
GAS LEAK TEST AT DISCH PRESS	○	
○ POST-TEST INTERNAL INSP		
○ BEFORE GAS LEAKAGE TEST		
○ AFTER GAS LEAKAGE TEST		
INTERMEDIATE HEAD/PRESSURE TOL.	○	
PERFORMANCE TEST	○	
COMPLETE UNIT TEST	○	
TANDEM TEST	○	
GEAR TEST	○	
HELIUM LEAK TEST	○	
SOUND LEVEL TEST (SURVEY ONLY)	○	
AUX. EQUIPMENT TEST ______	○	
FULL LOAD / SPEED / PRESS TEST	○	
HYDRAULIC COUPLING FIT INSP	○	
SPARE PARTS TEST ______	○	
INSPECTOR'S CHECKLIST COMPLIANCE	○	
GAS SEAL TEST VENDOR SHOP	○	
ADDITIONAL INSPECTION ______	○	

MANUALS
○ DRAFT MANUAL FOR REVIEW
○ TECHNICAL DATA MANUAL

MISCELLANEOUS:
☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
BEFORE SUCTION ______
○ COMPRESSOR TO BE SUITABLE FOR FIELD RUN-IN ON AIR
○ PROVISION FOR LIQUID INJECTION ______
○ INJECTION MANIFOLD
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEMS
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING/FOUNDATION
○ SHOP FITUP OF VENDOR PROCESS PIPING
○ WELDING HARDNESS TESTING
○ INSPECT CLEANLINESS ______
○ DESIGN AUDIT
○ BALANCE PISTON LINE ΔP VS THRUST LOAD CURVE
○ PROVIDE TAIL END SCHEDULES

VENDOR'S REPRESENTATIVE SHALL
○ OBSERVE FLANGE PARTING
○ CHECK ALIGNMENT AT TEMPERATURE
○ BE PRESENT AT INITIAL ALIGNMENT

☐ **WEIGHTS:** (kg)
COMPR. ______ GEAR ______ DRIVER ______ BASE ______
ROTORS: COMPR. ______ DRIVER ______ GEAR ______
COMPRESSOR UPPER CASE ______
MAX. FOR MAINTENANCE (IDENTIFY) ______
TOTAL SHIPPING WEIGHT ______

☐ **SPACE REQUIREMENTS:** (mm)
COMPLETE UNIT: L ______ W ______ H ______

SPECIAL TOOL PACKAGING:
○ METAL STORAGE CONTAINER
○ OTHER: ______

PAINTING:
○ MANUFACTURER'S STD.
○ OTHER ______

SHIPMENT:
○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQ'D.
○ OUTDOOR STORAGE MORE THAN 6 MONTHS ______ MONTH
SPARE ROTOR ASSEMBLY PACKAGE
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ METAL STORAGE CONTAINER
○ N2 PURGE ○ OTHER: ______
○ DGS removed for shipment

REMARKS: ______

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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)	REV/APPR					
SI UNITS (bar)	JOB NO. ______ ITEM NO. ______					
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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

2 FOR ______ UNIT ______

3 SITE ______ SERIAL NO. ______

4 SERVICE ______ NO. REQUIRED ______

5 MANUFACTURER ______ DRIVER TYPE ______

6 MODEL ______ DRIVER ITEM NO. ______

7 APPLICABLE STANDARD: ○ US ○ ISO

8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

9 **OPERATING CONDITIONS (SINGLE-COOLED CONFIGURATION)**

		NORMAL		OTHER CONDITIONS			
11	(ALL DATA ON PER UNIT BASIS)	Section 1	Section 2	Section 1	Section 2	Section 1	Section 2
12							
13	○ GAS HANDLED (ALSO SEE PAGE ____)						
14	△ GAS PROPERTIES						
15	○ STANDARD VOLUME FLOW (M^3/H - 1.013 barA & 0°C DRY)						
16	○ WEIGHT FLOW (kg/h) (WET) (DRY)						
17	**INLET CONDITIONS**						
18	○ PRESSURE (barA)						
19	○ TEMPERATURE (°C)						
20	○ RELATIVE HUMIDITY %						
21	○ MOLECULAR WEIGHT						
22	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
24	□ INLET VOLUME (m^3/h) (WET / DRY)						
25	**DISCHARGE CONDITIONS**						
26	○ PRESSURE (barA)						
27	□ TEMPERATURE (°C)						
28	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
30	□ GAS POWER REQUIRED (kW)						
31	□ TRAIN POWER REQUIRED (kW)						
32	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (kW)						
33	□ SPEED (rpm)						
34	□ TURNDOWN (%)						
35	□ POLYTROPIC HEAD (N-m/kg)						
36	□ POLYTROPIC EFFICIENCY (%)						
37	○ CERTIFIED POINT						
38	□ PERFORMANCE CURVE NUMBER						

39 **PROCESS CONTROL**

40 METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ COOLED BYPASS

41 FROM ______ (barA) GUIDE VANES FROM ______ % BLOWOFF FROM ______

42 TO ______ (barA) TO ______ % TO ______ TO ______

43 SIGNAL ○ SOURCE ______

44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______

45 RANGE ______ (mA) ______ (barG) ______

46 ○ START-UP ○ FROM SETTLE OUT CONDITION ○ NORMAL SUCTION PRESSURE ○ OTHER: ______

47 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

48 ______

49 ______

50 ______

51 ______

52 ______

53 ______

54 ______

55 ______

56 ______

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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2) **SI UNITS (bar)**	REV/APPR					

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APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
FOR ________ UNIT ________
SITE ________ SERIAL NO. ________
SERVICE ________ NO. REQUIRED ________
MANUFACTURER ________ DRIVER TYPE ________
MODEL ________ DRIVER ITEM NO. ________
APPLICABLE STANDARD: ○ US ○ ISO
INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

OPERATING CONDITIONS (COMPRESSOR WITH TWO SIDESTREAMS)

EQUIP.FLNG COND. SHOWN IN DBL-WALLED CELLS (ALL DATA ON PER UNIT BASIS)	**CONDITIONS**				
	Section 1	SS 1	Section 2	SS 2	Section 3
○ GAS HANDLED (ALSO SEE PAGE ____)					
△ GAS PROPERTIES					
○ STANDARD VOLUME FLOW (M³/H - 1.013 barA & 0°C DRY)					
○ WEIGHT FLOW (kg/h) (WET) (DRY)					
INLET CONDITIONS					
○ PRESSURE (barA)					
○ TEMPERATURE (°C)					
○ RELATIVE HUMIDITY %					
○ MOLECULAR WEIGHT					
□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)					
□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)					
□ INLET VOLUME (m³/h) (WET / DRY)					
DISCHARGE CONDITIONS					
○ PRESSURE (barA)					
□ TEMPERATURE (°C)					
□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)					
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)					
□ GAS POWER REQUIRED (kW)					
□ TRAIN POWER REQUIRED (kW)					
□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (kW)					
□ SPEED (rpm)					
□ TURNDOWN (%)					
□ POLYTROPIC HEAD (N-m/kg)					
□ POLYTROPIC EFFICIENCY (%)					
○ CERTIFIED POINT					
□ PERFORMANCE CURVE NUMBER					

PROCESS CONTROL

METHOD ○ SUCTION THROTTLING FROM ____ (barA) TO ____ (barA) ○ VARIABLE INLET GUIDE VANES ○ SPEED VARIATION FROM ____ % TO ____ % ○ DISCHARGE BLOWOFF TO ____ ○ COOLED BYPASS FROM ____ TO ____

SIGNAL ○ SOURCE ________
TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ________
RANGE ________ (mA) ________ (barG) ________

○ START-UP ○ FROM SETTLE OUT CONDITION ○ NORMAL SUCTION PARTS ○ OTHER: ________

REMARKS: NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

	REVISION	0	1	2	3	4
	DATE					
	BY					
CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2) **SI UNITS (bar)**	REV/APPR					
	JOB NO. ______		ITEM NO. ______			
	PAGE 12 OF 12		REQ'N NO. ______			

1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
2 FOR ______ UNIT ______
3 SITE ______ SERIAL NO. ______
4 SERVICE ______ NO. REQUIRED ______
5 MANUFACTURER ______ DRIVER TYPE ______
6 MODEL ______ DRIVER ITEM NO. ______
7 APPLICABLE STANDARD: ○ US ○ ISO
8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)
9 **OPERATING CONDITIONS (COMPRESSOR WITH TWO SIDESTREAMS)**

		CONDITIONS				
10	**EQUIP.FLNG COND. SHOWN IN DBL-WALLED CELLS**					
11	(ALL DATA ON PER UNIT BASIS)	Section 1	SS 1	Section 2	SS 2	Section 3
12						
13	○ GAS HANDLED (ALSO SEE PAGE ____)					
14	△ GAS PROPERTIES					
15	○ STANDARD VOLUME FLOW (M³/H - 1.013 barA & 0°C DRY)					
16	○ WEIGHT FLOW (kg/h) (WET) (DRY)					
17	**INLET CONDITIONS**					
18	○ PRESSURE (barA)					
19	○ TEMPERATURE (°C)					
20	○ RELATIVE HUMIDITY %					
21	○ MOLECULAR WEIGHT					
22	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)					
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)					
24	□ INLET VOLUME (m³/h) (WET / DRY)					
25	**DISCHARGE CONDITIONS**					
26	○ PRESSURE (barA)					
27	□ TEMPERATURE (°C)					
28	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)					
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)					
30	□ GAS POWER REQUIRED (kW)					
31	□ TRAIN POWER REQUIRED (kW)					
32	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (kW)					
33	□ SPEED (rpm)					
34	□ TURNDOWN (%)					
35	□ POLYTROPIC HEAD (N-m/kg)					
36	□ POLYTROPIC EFFICIENCY (%)					
37	○ CERTIFIED POINT					
38	□ PERFORMANCE CURVE NUMBER					

39 **PROCESS CONTROL**
40 METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ COOLED BYPASS
41 FROM ______ (barA) GUIDE VANES FROM ______ % BLOWOFF FROM ______
42 TO ______ (barA) TO ______ % TO ______ TO ______
43 SIGNAL ○ SOURCE ______
44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______
45 RANGE ______ (mA) ______ (barG) ______
46 ○ START-UP ○ FROM SETTLE OUT CONDITION ○ NORMAL SUCTION PARTS ○ OTHER: ______
47 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER
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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)

US CUSTOMARY

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BY					
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JOB NO. ______ ITEM NO. ______

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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

2 FOR ______ UNIT ______

3 SITE ______ SERIAL NO. ______

4 SERVICE ______ NO. REQUIRED ______

5 MANUFACTURER ______ DRIVER TYPE ______

6 MODEL ______ DRIVER ITEM NO. ______

7 APPLICABLE STANDARD: ○ US ○ ISO

8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

9 **OPERATING CONDITIONS (SINGLE-COOLED CONFIGURATION)**

Line		NORMAL	OTHER CONDITIONS A	B	C	D	E
10							
11	(ALL DATA ON PER UNIT BASIS)						
12							
13	○ GAS HANDLED (ALSO SEE PAGE ___)						
14	△ GAS PROPERTIES						
15	○ STANDARD VOLUME FLOW MMSCFD/SCFM (14.7 psia & 60°F DRY)						
16	○ WEIGHT FLOW (lbm/hr) (WET) (DRY)						
17	**INLET CONDITIONS**						
18	○ PRESSURE (psia)						
19	○ TEMPERATURE (°F)						
20	○ RELATIVE HUMIDITY %						
21	○ MOLECULAR WEIGHT						
22	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
24	□ INLET VOLUME (cfm) (WET / DRY)						
25	**DISCHARGE CONDITIONS**						
26	○ PRESSURE (psia)						
27	□ TEMPERATURE (°F)						
28	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
30	□ GAS POWER REQUIRED (HP)						
31	□ TRAIN POWER REQUIRED (HP)						
32	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (HP)						
33	□ SPEED (rpm)						
34	□ TURNDOWN (%)						
35	□ POLYTROPIC HEAD (ft-lbf/lbm)						
36	□ POLYTROPIC EFFICIENCY (%)						
37	○ CERTIFIED POINT						
38	□ PERFORMANCE CURVE NUMBER						

39 **PROCESS CONTROL**

40 METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ COOLED BYPASS

41 FROM ______ (psia) GUIDE VANES FROM ______ % BLOWOFF FROM ______

42 TO ______ (psia) TO ______ % TO ______ TO ______

43 SIGNAL ○ SOURCE ______

44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______

45 RANGE ______ (mA) ______ (psig) ______

46 START-UP ○ FROM SETTLE OUT CONDITION ○ NORMAL SUCTION PRESSURE ○ OTHER: ______

47 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

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JOB NO. ______ ITEM NO. ______
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		NORMAL	A	B	C	D	E
1	**OPERATING CONDITIONS**						
2		NORMAL	OTHER CONDITIONS				
3	(ALL DATA ON PER UNIT BASIS)		A	B	C	D	E
4							
5	○ GAS HANDLED (ALSO SEE PAGE ____)						
6	△ GAS PROPERTIES						
7	○ MMSCFD/SCFM (14.7 psia & 60°F DRY)						
8	○ WEIGHT FLOW (lbm/hr) (WET) (DRY)						
9	**INLET CONDITIONS**						
10	○ PRESSURE (psia)						
11	○ TEMPERATURE (°F)						
12	○ RELATIVE HUMIDITY %						
13	○ MOLECULAR WEIGHT						
14	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
15	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
16	□ INLET VOLUME (cfm) (WET / DRY)						
17	**DISCHARGE CONDITIONS**						
18	○ PRESSURE (psia)						
19	□ TEMPERATURE (°F)						
20	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
21	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
22	□ GAS POWER REQUIRED (HP)						
23	□ TRAIN POWER REQUIRED (HP)						
24	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (HP)						
25	□ SPEED (rpm)						
26	□ TURNDOWN (%)						
27	□ POLYTROPIC HEAD (ft-lbf/lbm)						
28	□ POLYTROPIC EFFICIENCY (%)						
29	○ CERTIFIED POINT						
30	□ PERFORMANCE CURVE NUMBER						

31 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER
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OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)	NORMAL	OTHER CONDITIONS A	B	C	D	E
○ GAS HANDLED (ALSO SEE PAGE ____)						
△ GAS PROPERTIES						
○ MMSCFD/SCFM (14.7 psia & 60°F DRY)						
○ WEIGHT FLOW (lbm/hr) (WET) (DRY)						
INLET CONDITIONS						
○ PRESSURE (psia)						
○ TEMPERATURE (°F)						
○ RELATIVE HUMIDITY %						
○ MOLECULAR WEIGHT						
□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
□ INLET VOLUME (cfm) (WET / DRY)						
DISCHARGE CONDITIONS						
○ PRESSURE (psia)						
□ TEMPERATURE (°F)						
□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
□ GAS POWER REQUIRED (HP)						
□ TRAIN POWER REQUIRED (HP)						
□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (HP)						
□ SPEED (rpm)						
□ TURNDOWN (%)						
□ POLYTROPIC HEAD (ft-lbf/lbm)						
□ POLYTROPIC EFFICIENCY (%)						
○ CERTIFIED POINT						
□ PERFORMANCE CURVE NUMBER						

REMARKS: NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
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OPERATING CONDITIONS (Continued)

GAS ANALYSIS:			OTHER CONDITIONS					
○ MOL %		NORMAL	A	B	C	D	E	REMARKS:
	MW							
AIR	28.966							
OXYGEN	32.000							
NITROGEN	28.016							
WATER VAPOR	18.016							
CARBON MONOXIDE	28.010							
CARBON DIOXIDE	44.010							
HYDROGEN SULFIDE	34.076							
HYDROGEN	2.016							
METHANE	16.042							
ETHYLENE	28.052							
ETHANE	30.068							
PROPYLENE	42.078							
PROPANE	44.094							
I-BUTANE	58.120							
n-BUTANE	58.120							
I-PENTANE	72.146							
n-PENTANE	72.146							
HEXANE PLUS								
CORROSIVE AGENTS								
TOTAL								
AVG. MOL. WT.								

LOCATION:
○ INDOOR ○ OUTDOOR ○ GRADE
○ HEATED ○ UNDER ROOF ○ MEZZANINE
○ UNHEATED ○ PARTIAL SIDES ○ ______
SITE DATA
○ ELEVATION ______ (ft) BAROMETER ______ (psia)
○ RANGE OF AMBIENT TEMPS:

		DRY BULB	WET BULB
NORMAL	(°F)	______	______
MAXIMUM	(°F)	______	______
MINIMUM	(°F)	______	______
______	(°F)	______	______

UNUSUAL CONDITIONS: ○ DUST ○ FUMES
______ ______ ______
○ OTHER ______
______
○ COPPER AND COPPER ALLOYS PROHIBITED
COATING:
○ ROTATING COMPONENTS ______
○ STATIONARY COMPONENTS ______
REMARKS: ______

NOISE SPECIFICATIONS:
○ APPLICABLE TO MACHINE:
SEE SPECIFICATION ______
○ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION ______
ACOUSTIC HOUSING: ○ YES ○ NO
APPLICABLE SPECIFICATIONS:
API 617-9th
○ VENDOR HAVING UNIT RESPONSIBILITY
______
○ GOVERNING SPECIFICATION (IF DIFFERENT)
______

○ ELEC. AREA CLASS. ○ NEC ○ IEC
EQUIPMENT
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______
CONTROL PANNELS
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______

○ **INSTRUMENT AND CONTROLS**
STANDARD ○ NEMA ○ IEC

	INDOOR	OUTDOOR
CONTROL ENCLOSURE	______	______
TERMINAL BOX	______	______

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CENTRIFUGAL AND AXIAL COMPRESSOR
DATASHEET (API 617-9th, Part 2)
US CUSTOMARY

JOB NO. ______ ITEM NO. ______
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CONSTRUCTION FEATURES

☐ **SPEEDS:**
MAX. CONT. ______ (rpm) TRIP ______ (rpm)
MAX. TIP SPEEDS: ______ (fps) @ 100% SPEED
______ (fps) @ MAX. CONT. SPEED

☐ **LATERAL CRITICAL SPEEDS (DAMPED)**
FIRST CRITICAL ______ (rpm) ______ MODE
SECOND CRITICAL ______ (rpm) ______ MODE
THIRD CRITICAL ______ (rpm) ______ MODE
FOURTH CRITICAL ______ (rpm) ______ MODE
○ LATERAL ANALYSIS ADDITIONAL REQUIREMENTS
○ TRAIN LATERAL ANALYSIS REQUIRED
○ TORSIONAL ANALYSIS REQUIRED

☐ **TORSIONAL CRITICAL SPEEDS:**
FIRST CRITICAL ______ (rpm)
SECOND CRITICAL ______ (rpm)
THIRD CRITICAL ______ (rpm)
FOURTH CRITICAL ______ (rpm)
○ LIST OF TRAIN UNDESIRABLE SPEEDS
○ STABILITY ANALYSIS

☐ **VIBRATION:**
ALLOWABLE RADIAL TEST LEVEL (mil P-P) ______
ALLOWABLE AXIAL TEST LEVEL (mil P-P) ______

NAMEPLATE
○ US CUSTOMARY ○ METRIC

☐ **ROTATION, VIEWED FROM DRIVEN END** ○ CW ○ CCW

○ **MATERIALS INSPECTION REQUIREMENTS**
○ RADIOGRAPHY REQUIRED FOR ______
○ ULTRASONIC REQUIRED FOR ______
○ MAGNETIC PARTICLE REQUIRED FOR ______
○ LIQUID PENETRANT REQUIRED FOR ______
○ LOW TEMPERATURE ______
MIN.DESIGN METAL TEMPERATURE (°F) ______
AT CONCURRENT PRESSURE (psig) ______
○ OTHER TRAIN COMPONENTS

☐ **CASING:**
MODEL ______
CASING SPLIT ______
MATERIAL ______
THICKNESS (in) ______ CORR. ALLOW. (in) ______
MAX. ALLOWABLE PRESS ______ (psig)
TEST PRESS: (psig) HELIUM ______ HYDRO ______
MAX. ALLOWABLE TEMPERATURE ______ (°F)
MAX OPER. TEMP. ______ (°F) MIN. OPER. TEMP. ______ (°F)
MAX CASING CAPACITY ______ (icfm)
○ SYSTEM RELIEF VALVE SET PT. ______ (psig)
○ Q.C. OF INACCESSIBLE WELDS

☐ **DIAPHRAGMS:**
MATERIAL ______
AXIALLY SPLIT ☐ YES ☐ NO
DIAPHRAGM MAX. ∆ P (BAR)(kPa):

○ **INTERMEDIATE MAIN PROCESS CONNECTIONS**
DISCH. PRESSURE: (psig) MAX ______ MIN ______
INLET PRESSURE: (psig) MAX ______ MIN ______

☐ **GUIDE VANES**
○ IGV EXTERNAL PURGE ______
○ VANE CONTROL SYSTEM ______
NUMBER OF AXIAL BLADE ROWS ______
NUMBER OF ADJUSTIBLE ROWS ______
NO. VANES GUIDE VANE ______ MATERIAL ______

☐ **IMPELLERS:**
NO. ______ DIAMETERS ______
NO. VANES EA. IMPELLER ______
TYPE (OPEN, ENCLOSED, ETC.) ______
TYPE FABRICATION ______ MATERIAL ______
MIN. YIELD STRENGTH (psi) ______
HARDNESS: (Rc) (BRINNEL) MAX ______ MIN ______
SMALLEST TIP INTERNAL WIDTH (in) ______
MAX. MACH. NO. @ IMPELLER EYE ______
MAX. IMPELLER HEAD @ 100% SPD (ft-lb/lb) ______

☐ **SHAFT:**
○ ONE PIECE ○ BUILT UP
MATERIAL ______
DIA @ IMPELLERS (in) ______ DIA @ COUPLING (in) ______
SHAFT END: ○ TAPERED ○ CYLINDRICAL
○ SPLINED ○ INTEGRAL FLANGE
MIN. YIELD STRENGTH (psi) ______
SHAFT HARDNESS (BNH)(Rc) ______
MAX TORQUE CAPABILITY (ft-lb) ______

☐ **BALANCE PISTON:**
MATERIAL ______ AREA ______ (in.²)
FIXATION METHOD ______
NORMAL CLEARANCE (in) ______
FLOW WITH NORMAL CLEARANCE (lbm/min) ______
FLOW WITH 2x NORMAL CLEARANCE (lbm/min) ______
○ PRESS. CONN. BAL LINE DOWNSTREAM ● GAUGE ● TRANSMITTER

☐ **SHAFT SLEEVES:**
AT INTERSTG. CLOSE MATL ______
CLEARANCE POINTS
AT SHAFT SEALS MATL ______
○ ACCESSIBLE

ROTOR
○ ______
○ AT SPEED BALANCING
○ SEQUENTIAL LOW SPEED BAL. PREC. AT SPEED BAL.
○ RESIDUAL UNBALANCE CHECK

☐ **LABYRINTHS:**
INTERSTAGE
TYPE ______ MATERIAL ______
BALANCE PISTON
TYPE ______ MATERIAL ______

REMARKS: ______

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LOW-PRESSURE CASING CONSTRUCTION FEATURES (CONTINUED)

SHAFT SEALS:
- ○ SEAL TYPE ______
- ○ SETTLE OUT PRESSURE (psig) ______
- ○ MIN.SEALING PRESSURE (psig) ______
- ○ SUPPLEMENTAL DEVICE REQUIRED FOR CONTACT SEALS TYPE ______
- ○ BUFFER GAS SYSTEM REQUIRED ______
- ○ TYPE BUFFER GAS ______
  - ☐ PRESSURE ______ (psig)
  - ☐ FLOW RATE ______ (lbm/min)
  - ☐ FILTRATION ______ (µm)
- ○ MANIFOLD
- ○ METHOD OF CONTROL

- ○ BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR
- ○ PRESSURIZING GAS FOR SUBATMOSPHERIC SEALS
  - ○ EDUCTOR ○ INJECTION
- ☐ SEAL MANUFACTURER

FOR COMPLETE INFORMATION SEE API 692 DATASHEET

BEARING HOUSING:
- ☐ **BEARING HOUSING CONSTRUCTION:**
  - TYPE (SEPARATE, INTEGRAL) ______ SPLIT ______
  - MATERIAL ______

AXIAL COMPRESSOR

STAGE	1	2	3	4	5	6	7	8	9
ROTOR									
☐ BLADE MATERIAL									
☐ BLADE ROOT TYPE									
☐ CORD WIDTH (in)									
☐ OUTER DIAMETER (in)									
☐ BLADE HEIGHT (in)									
☐ BLADE QUANTITY									
STATOR									
☐ BLADE MATERIAL									
☐ TYPE (FIXED OR VARIABLE)									
☐ CORD WIDTH (in)									
☐ BLADE QUANTITY									

STAGE	10	11	12	13	14	15	16	17	18
ROTOR									
☐ BLADE MATERIAL									
☐ BLADE ROOT TYPE									
☐ CORD WIDTH (in)									
☐ OUTER DIAMETER (in)									
☐ BLADE HEIGHT (in)									
☐ BLADE QUANTITY									
STATOR									
☐ BLADE MATERIAL									
☐ TYPE (MOVABLE, FIXED, ADJUSTABLE)									
☐ CORD WIDTH (in)									
☐ BLADE QUANTITY									

REMARKS: ______

	REVISION	0	1	2	3	4
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CONSTRUCTION FEATURES (CONTINUED)

BEARINGS AND BEARING HOUSINGS

○ ACTIVE MAGNETIC BEARINGS

RADIAL	THRUST	NON-THRUST
☐ TYPE		
☐ MANUFACTURER		
☐ LENGTH (in)		
☐ SHAFT DIA. (in)		
☐ UNIT LOAD (ACT/ALLOW) (psi)		
☐ BASE MATERIAL		
☐ BABBIT THICKNESS (in)		
☐ NO. PADS		
☐ LOAD: B'TWN/ON PAD		
☐ PIVOT: CTR/OFFSET, %		

PAD MATERIAL ○ STEEL BACKED ○ COPPER BACKED
☐ BEARING SPAN (in) ______

THRUST	ACTIVE	INACTIVE
☐ TYPE		
☐ MANUFACTURER		
☐ UNIT LOADING - MAX (psi)		
☐ UNIT LOAD - ULT. (psi)		
☐ AREA (in.²)		
☐ NO. PADS		
☐ PIVOT: CENTER / OFFSET, %		
☐		

PAD MATERIAL ○ STEEL BACKED ○ COPPER BACKED
LUBRICATION: ○ FLOODED ○ DIRECTED
THRUST COLLAR: ○ INTEGRAL ○ REPLACEABLE
MATERIAL ______
☐ SIZING CRITERIUM ______

BEARING TEMPERATURE DETECTORS

○ SEE ATTACHED API-670 DATASHEET
○ THERMOCOUPLES TYPE ______
○ RESISTANCE TEMP DETECTORS
○ RESISTANCE MAT'L ______ ○ ______ (ohms)
☐ ALARM TEMPERATURE ______ (°F)
☐ SHUTDOWN TEMPERATURE ______ (°F)
○ PROVISION FOR LOCAL DISCONNECT
○ LOCATION-JOURNAL BRG
NO. ___ EA PAD ______ EVERY OTH PAD ___ PER BRG
OTHER ______
○ LOCATION-THRUST BRG
NO. ___ EA PAD ______ EVERY OTH PAD ___ PER BRG
OTHER ______
NO. (INACT) ___ EA PAD ___ EVERY OTH PAD ___ PER BRG
OTHER ______
○ LOCAL DISCONNECTION
○ MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR. ______ ☐ MODEL ______
☐ SCALE RGE ______ ○ ALARM ☐ SET @ ______ (°F)
○ SHTDWN ☐ SET @ ___ (°F) ○ TIME DELAY ___ (sec)

VIBRATION DETECTORS:

○ SEE ATTACHED API 670 DATASHEET
○ TYPE ______ ☐ MODEL ______
○ MFR ______
○ NO. AT EA SHAFT BEARING ______ TOTAL NO. ______
○ OSCILLATOR-DETECTORS SUPPLIED BY ______
○ MFR ______ ☐ MODEL ______
MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR. ______ ☐ MODEL ______
☐ SCALE RGE ___ ○ ALARM ☐ SET @ ______ (mil)
○ SHTDWN: ☐ SET @ ___ (mil) ○ TIME DELAY ___ (sec)
○ CASING VIBRATION TRANSDUCERS
○ CASING VIBRATION MONITORS

AXIAL POSITION/VIBRATION DETECTOR:

○ SEE ATTACH. API-670 DATASHEET
○ TYPE ______ ☐ MODEL ______
● MFR ______ ○ NO. REQUIRED ______
○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
○ MFR ______ ☐ MODEL ______
○ MONITOR SUPPLIED BY ______
○ LOCATION ______ ENCLOSURE ______
○ MFR. ______ ☐ MODEL ______
☐ SCALE RGE ______ ○ ALARM ☐ SET @ ______ (mil)
○ SHTDWN: ☐ SET @ ___ (mil) ○ TIME DELAY ___ (sec)

KEY PHASOR REQUIRED

○ COMPRESSOR ○ GEAR H.S. ○ GEAR L.S.

CASING CONNECTIONS

CONNECTION	☐ ANSI/ASME (B16.1; B16.5; B16.42; B16.47 series A, B; EN 1092-1, -2; OTHER)	☐ FACING ☐ BORE	○ ORIENTATION	○ FLANGED OR STUDDED	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY (fps)
INLET						
DISCHARGE						

○ BORESCOPIC INSPECTION PORTS

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1	☐ **OTHER CONNECTIONS**								
2	**SERVICE:**	**NO.**	**SIZE**	**TYPE**		**NO.**	**SIZE**	**TYPE**	
3	LUBE-OIL INLET				PRESSURE				
4	LUBE OIL OUTLET				TEMPERATURE				
5	SEAL-OIL INLET				SOLVENT INJECTION				
6	SEAL-OIL OUTLET				PURGE FOR:				
7	SEAL GAS INLET				BRG. HOUSING				
8	SEAL GAS OUTLET				BTWN BRG & SEAL				
9	CASING DRAINS				BTWN SEAL & GAS				
10	STAGE DRAINS								
11	○ INDIVIDUAL STAGE DRAINS REQUIRED								
12	○ VALVED & BLINDED								
13	○ VALVED & BLINDED & MANIFOLD								
14	**LUBRICATION AND SEALING SYSTEMS**								
15	○ SEE ATTACHED API 614 DATASHEET								
16	○ SEPARATE ○ COMBINED								
17	○ INTEGRAL OIL RESERVOIR								
18	△ OIL TYPE								
19	**ACCESSORIES**								
20	**COUPLING AND GUARDS**								
21	NOTE: SEE ROTATING ELEMENTS - SHAFT ENDS								
22	○ SEE ATTACHED API 671 DATASHEET	○ KEYLESS HYDRAULIC	○ KEYED	○ FLANGED	○ OTHER				
23	COUPLING FURNISHED BY		MOUNTED BY						
24	MANUFACTURER		TYPE		MODEL				
25	COUPLING GUARD FURNISHED BY:								
26	TYPE: ○ FULLY ENCLOSED	○ SEMI-OPEN	○ OTHER						
27	**COUPLING DETAILS**								
28	☐ MAX O.D.	(in)	○ PLUG AND RING GAUGES	○ LAPPING TOOL					
29	☐ HUB WEIGHT	(lb)	COOLING REQUIREMENTS						
30	☐ SPACER LENGTH	(in)	■ FLOW RATE	(gpm)					
31	☐ SPACER WEIGHT	(lb)							
32	**MOUNTING PLATES**								
33	○ BASEPLATES FURNISHED BY		○ SOLEPLATES FURNISHED BY						
34	○ COMPRESSOR ONLY	○ DRIVER ○ GEAR	☐ THICKNESS	(in)					
35	○ OTHER		○						
36	○ NONSKID DECKING	○ SLOPED DECK	○ EXTENT OF PIPING						
37	△ LEVELING PADS OR TARGETS		☐ SHIM THICKNESS	(in)					
38	△ COLUMN MOUNTING								
39	○ SUB-SOLE PLATES REQUIRED								
40	☐ SHIM THICKNESS	(in)	○ COUNTER BORE ANCHOR BOLT HOLES						
41	○ MACHINED MOUNTING PADS REQUIRED								
42	ANTI-SURGE SYSTEM	FURNISHED BY ○ PURCHASER	☐ VENDOR						
43	○ ☐ ANTI-SURGE VALVE	○ SIZING ONLY							
44		PRESSURE UPSTREAM:	(psig) DOWNSTREAM Δ P	(psi)					
45		☐ Δ P VALVE	STROKE TIME OPEN - CLOSE	(sec)					
46	○ ☐ RECIRCULATION VALVE	○ SIZING ONLY	**REMARKS:**						
47	○ ☐ BLOWOFF VALVE	○ SIZING ONLY							
48	○ ☐ CONTROL SYSTEM								
49	○ ☐ PIPING								
50	○ ☐ FLOW ELEMENT								
51	○ ☐	○ ☐							
52	○ ☐	○ ☐							
53	○ ☐	○ ☐							
54	○ ☐	○ ☐							
55	○ ☐	○ ☐							
56	○ ☐	○ ☐							

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UTILITIES

○ UTILITY CONDITIONS:

STEAM: **DRIVERS**

INLET MIN		(psig)		(°F)
NORM		(psig)		(°F)
MAX		(psig)		(°F)
EXHAUST. MIN		(psig)		(°F)
NORM		(psig)		(°F)
MAX		(psig)		(°F)

ELECTRICITY:

	DRIVERS	CONTROL	SHUTDOWN
VOLTAGE			
HERTZ			
PHASE			

○ REDUCED VOLTAGE START
△ NUMBER OF STARTS ______

INSTRUMENT AIR:
MAX PRESS ______ (psig) MIN PRESS ______ (psig)

SHOP INSPECTION AND TESTS:

○ (SEE INSPECTOR'S CHECKLIST)	REQ'D	WIT/OBV
HYDROSTATIC	●	
IMPELLER OVERSPEED	●	
MECHANICAL RUN	●	
○ CONTRACT COUPLING ○ IDLING ADAPTOR(S)		
○ CONTRACT PROBES ○ SHOP PROBES		
○ PURCHASER VIB. EQUIPMENT		
○ VARY LUBE OIL PRESSURES AND TEMPERATURES		
○ UNBALANCE VERIFICATION TEST		
POLAR FORM VIB DATA	○	
RECORD VIB DATA	○	
SHAFT END SEAL INSP	○	
GAS LEAK TEST AT DISCH PRESS	○	
○ POST TEST INTERNAL INSP		
○ BEFORE GAS LEAKAGE TEST		
○ AFTER GAS LEAKAGE TEST		
INTERMEDIATE HEAD/PRESSURE TOL.	○	
PERFORMANCE TEST	○	
COMPLETE UNIT TEST	○	
TANDEM TEST	○	
GEAR TEST	○	
HELIUM LEAK TEST	○	
SOUND LEVEL TEST (SURVEY ONLY)	○	
AUX. EQUIPMENT TEST ______	○	
FULL LOAD / SPEED / PRESS TEST	○	
HYDRAULIC COUPLING FIT INSP	○	
SPARE PARTS TEST ______	○	
INSPECTOR'S CHECKLIST COMPLIANCE	○	
GAS SEAL TEST VENDOR SHOP	○	
ADDITIONAL INSPECTION ______	○	

MANUALS

○ DRAFT MANUAL FOR REVIEW
○ TECHNICAL DATA MANUAL

MISCELLANEOUS:

☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
BEFORE SUCTION ______
○ COMPRESSOR TO BE SUITABLE FOR FIELD RUN-IN ON AIR
○ PROVISION FOR LIQUID INJECTION ______
○ INJECTION MANIFOLD
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEMS
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING/FOUNDATION
○ SHOP FITUP OF VENDOR PROCESS PIPING
○ WELDING HARDNESS TESTING
○ INSPECT CLEANLINESS ______
○ DESIGN AUDIT
○ BALANCE PISTON LINE ΔP VS. THRUST LOAD CURVE
○ PROVIDE TAIL END SCHEDULES

VENDOR'S REPRESENTATIVE SHALL

○ OBSERVE FLANGE PARTING
○ CHECK ALIGNMENT AT TEMPERATURE
○ BE PRESENT AT INITIAL ALIGNMENT

☐ WEIGHTS: (lb)

COMPR. ______ GEAR ______ DRIVER ______ BASE ______
ROTORS: COMPR. ______ DRIVER ______ GEAR ______
COMPRESSOR UPPER CASE ______
MAX. FOR MAINTENANCE (IDENTIFY) ______
TOTAL SHIPPING WEIGHT ______

☐ SPACE REQUIREMENTS: (in)

COMPLETE UNIT: L ______ W ______ H ______

SPECIAL TOOL PACKAGING

○ METAL STORAGE CONTAINER
○ OTHER: ______

PAINTING:

○ MANUFACTURER'S STD.
○ OTHER ______

SHIPMENT:

○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQ'D.
○ OUTDOOR STORAGE MORE THAN 6 MONTHS ______ MONTH
SPARE ROTOR ASSEMBLY PACKAGE
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ METAL STORAGE CONTAINER
○ N2 PURGE ○ OTHER: ______
○ DGS REMOVED FOR SHIPMENT

REMARKS: ______

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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
2 FOR ______ UNIT ______
3 SITE ______ SERIAL NO. ______
4 SERVICE ______ NO. REQUIRED ______
5 MANUFACTURER ______ DRIVER TYPE ______
6 MODEL ______ DRIVER ITEM NO. ______
7 APPLICABLE STANDARD: ○ US ○ ISO
8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ MUTUAL AGREEMENT (PRIOR TO PURCHASE)

9 **OPERATING CONDITIONS (SINGLE-COOLED CONFIGURATION)**

		NORMAL		OTHER CONDITIONS			
11	(ALL DATA ON PER UNIT BASIS)	Section 1	Section 2	Section 1	Section 2	Section 1	Section 2
12							
13	○ GAS HANDLED (ALSO SEE PAGE ____)						
14	△ GAS PROPERTIES						
15	○ MMSCFD/SCFM (14.7 psia & 60°F DRY)						
16	○ WEIGHT FLOW (lb/hr) (WET) (DRY)						
17	**INLET CONDITIONS**						
18	○ PRESSURE (psia)						
19	○ TEMPERATURE (°F)						
20	○ RELATIVE HUMIDITY %						
21	○ MOLECULAR WEIGHT						
22	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)						
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)						
24	□ INLET VOLUME, (cfm) (WET / DRY)						
25	**DISCHARGE CONDITIONS**						
26	○ PRESSURE (psia)						
27	□ TEMPERATURE (°F)						
28	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)						
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)						
30	□ GAS POWER REQUIRED (HP)						
31	□ TRAIN POWER REQUIRED (HP)						
32	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (HP)						
33	□ SPEED (rpm)						
34	□ TURNDOWN (%)						
35	□ POLYTROPIC HEAD (ft-lb/lb)						
36	□ POLYTROPIC EFFICIENCY (%)						
37	○ CERTIFIED POINT						
38	□ PERFORMANCE CURVE NUMBER						

39 **PROCESS CONTROL**
40 METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ COOLED BYPASS
41 FROM ______ (psia) GUIDE VANES FROM ______ % BLOWOFF FROM ______
42 TO ______ (psia) TO ______ % TO ______ TO ______
43 SIGNAL ○ SOURCE ______
44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______
45 RANGE ______ MA ______ (psig) ______
46 ○ START-UP ○ FROM SETTLING OUT CONDITION ○ NORMAL SUCTION PARTS ○ OTHER: ______
47 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER
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CENTRIFUGAL AND AXIAL COMPRESSOR DATASHEET (API 617-9th, Part 2)
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JOB NO. ______ ITEM NO. ______

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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

2 FOR ______ UNIT ______

3 SITE ______ SERIAL NO. ______

4 SERVICE ______ NO. REQUIRED ______

5 MANUFACTURER ______ DRIVER TYPE ______

6 MODEL ______ DRIVER ITEM NO. ______

7 APPLICABLE STANDARD: ○ US ○ ISO

8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ MUTUAL AGREEMENT (PRIOR TO PURCHASE)

9 **OPERATING CONDITIONS (COMPRESSOR WITH TWO SIDESTREAMS)**

		CONDITIONS				
10	**EQUIP. FLNG COND. SHOWN IN DBL-WALLED CELLS**					
11	(ALL DATA ON PER UNIT BASIS)	Section 1	SS 1	Section 2	SS 2	Section 3
12						
13	○ GAS HANDLED (ALSO SEE PAGE ____)					
14	△ GAS PROPERTIES					
15	○ MMSCFD/SCFM (14.7 psia & 60°F DRY)					
16	○ WEIGHT FLOW (lb/hr) (WET) (DRY)					
17	**INLET CONDITIONS**					
18	○ PRESSURE (psia)					
19	○ TEMPERATURE (°F)					
20	○ RELATIVE HUMIDITY %					
21	○ MOLECULAR WEIGHT					
22	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)					
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)					
24	□ INLET VOLUME (cfm) (WET / DRY)					
25	**DISCHARGE CONDITIONS**					
26	○ PRESSURE (psia)					
27	□ TEMPERATURE (°F)					
28	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)					
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)					
30	□ GAS POWER REQUIRED (HP)					
31	□ TRAIN POWER REQUIRED (HP)					
32	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (HP)					
33	□ SPEED (rpm)					
34	□ TURNDOWN (%)					
35	□ POLYTROPIC HEAD (ft-lb/lb)					
36	□ POLYTROPIC EFFICIENCY (%)					
37	○ CERTIFIED POINT					
38	□ PERFORMANCE CURVE NUMBER					

39 **PROCESS CONTROL**

40 METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ COOLED BYPASS

41 FROM ______ (psia) GUIDE VANES FROM ______ % BLOWOFF FROM ______

42 TO ______ (psia) TO ______ % TO ______ TO ______

43 SIGNAL ○ SOURCE ______

44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______

45 RANGE ______ MA ______ (psig) ______

46 ○ START-UP ○ FROM SETTLING OUT CONDITION ○ NORMAL SUCTION PARTS ○ OTHER: ______

47 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER

48 ______

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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
2 FOR ______ UNIT ______
3 SITE ______ SERIAL NO. ______
4 SERVICE ______ NO. REQUIRED ______
5 MANUFACTURER ______ DRIVER TYPE ______
6 MODEL ______ DRIVER ITEM NO. ______
7 APPLICABLE STANDARD: ○ US ○ ISO
8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ MUTUAL AGREEMENT (PRIOR TO PURCHASE)
9 **OPERATING CONDITIONS (COMPRESSOR WITH TWO SIDESTREAMS)**

		CONDITIONS				
10	**EQUIP.FLNG COND. SHOWN IN DBL-WALLED CELLS**					
11	(ALL DATA ON PER UNIT BASIS)	Section 1	SS 1	Section 2	SS 2	Section 3
12						
13	○ GAS HANDLED (ALSO SEE PAGE ____)					
14	△ GAS PROPERTIES					
15	○ MMSCFD/SCFM (14.7 psia & 60°F DRY)					
16	○ WEIGHT FLOW (lb/hr) (WET) (DRY)					
17	**INLET CONDITIONS**					
18	○ PRESSURE (psia)					
19	○ TEMPERATURE (°F)					
20	○ RELATIVE HUMIDITY %					
21	○ MOLECULAR WEIGHT					
22	□ Cp/Cv (K_1) OR (K_{AVG}) (NOTE 1)					
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG}) (NOTE 1)					
24	□ INLET VOLUME (cfm) (WET / DRY)					
25	**DISCHARGE CONDITIONS**					
26	○ PRESSURE (psia)					
27	□ TEMPERATURE (°F)					
28	□ Cp/Cv (K_2) OR (K_{AVG}) (NOTE 1)					
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG}) (NOTE 1)					
30	□ GAS POWER REQUIRED (HP)					
31	□ TRAIN POWER REQUIRED (HP)					
32	□ POWER REQ'D AT DRIVER INCL. EXT. LOSSES (HP)					
33	□ SPEED (rpm)					
34	□ TURNDOWN (%)					
35	□ POLYTROPIC HEAD (ft-lb/lb)					
36	□ POLYTROPIC EFFICIENCY (%)					
37	○ CERTIFIED POINT					
38	□ PERFORMANCE CURVE NUMBER					

39 **PROCESS CONTROL**
40 METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ COOLED BYPASS
41 FROM ______ (psia) GUIDE VANES FROM ______ % BLOWOFF FROM ______
42 TO ______ (psia) TO ______ % TO ______ TO ______
43 SIGNAL ○ SOURCE ______
44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______
45 RANGE ______ MA ______ (psig) ______
46 ○ START-UP ○ FROM SETTLING OUT CONDITION ○ NORMAL SUCTION PARTS ○ OTHER: ______
47 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY DATA, OTHERWISE DATA SHALL BE SUPPLIED BY USER
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Annex B
(informative)

Vendor Drawing and Data Requirements

B.1 VDDR for Centrifugal and Axial Compressors (See Text for Details of the Description)

CENTRIFUGAL AND AXIAL COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	**Distribution Record** Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	1. Certified dimensional outline drawing and list of connections					
/	/	/	2. Cross-sectional drawings and part numbers					
/	/	/	3. Rotor assembly drawings and part numbers					
/	/	/	4. Thrust-bearing assembly drawings and part numbers					
/	/	/	5. Journal-bearing assembly drawings and bill of materials					
/	/	/	6. Coupling assembly drawings and bill of materials					
/	/	/	7. Lube-oil schematic and bill of materials					
/	/	/	8. Lube-oil arrangement drawing and list of connections					
/	/	/	9. Lube-oil component drawings and data					
/	/	/	10. Seal system schematic and bill of materials					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.
[b] Purchase may indicate in the column the desired time frame for submission of data.
[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

CENTRIFUGAL AND AXIAL COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	**Distribution Record** Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	11. Seal system arrangement drawing and list of connections					
/	/	/	12. Seal system component drawings and data					
/	/	/	13. Seal assembly drawing and part numbers					
/	/	/	14. Electrical and instrumentation schematics and bill of materials					
/	/	/	15. Electrical and instrumentation arrangement drawing and list of connections					
/	/	/	16. Buffer gas system schematic and bill of materials					
/	/	/	17. Buffer gas system arrangement drawing and list of connections					
/	/	/	18. Buffer gas system component drawing and data					
/	/	/	19. Datasheets (proposal/as-built)					
/	/	/	20. Predicted noise sound level (proposal)					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

CENTRIFUGAL AND AXIAL COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	21. Metallurgy of major components (in proposal)					
/	/	/	22. Lateral analysis report and stability analysis (if required)					
/	/	/	23. Torsional analysis report					
/	/	/	24. Vibration analysis report					
/	/	/	25. Performance curves for each compressor section (proposal/as-built)					
/	/	/	26. Impeller overspeed test report					
/	/	/	27. Mechanical running test report					
/	/	/	28. Coupling selection and rating					
/	/	/	29. List of recommended spare parts					
/	/	/	30. List of special tools					
/	/	/	31. Preparation for storage at job site before installation					

Distribution Record

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

CENTRIFUGAL AND AXIAL COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	32. Weather protection and winterization required at job site					
/	/	/	33. Tabulation of all utilities					
/	/	/	34. List of similar machines					
/	/	/	35. Operating restrictions to protect equipment during start-up operation and shutdown					
/	/	/	36. List of components requiring purchaser's approval					
/	/	/	37. Summary of materials and hardness of materials exposed to H_2S					
/	/	/	38. Seal leakage rates					
/	/	/	39. Interstage cooler system data					
/	/	/	40. Drawings, details, and description of instrumentation and controls					
/	/	/	41. Minimum length of straight pipe required at machine inlet or side inlets					
/	/	/	42. Maximum and minimum allowable seal pressure for each compressor					

Distribution Record: columns Review Due from Vendor through Final Received from Vendor.

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

CENTRIFUGAL AND AXIAL COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	43. Statement of manufacturer’s testing capabilities					
/	/	/	44. Performance test data and curves					
/	/	/	45. Back-to-back impeller machine vendor to provide thrust-bearing loads vs differential pressure curve					
/	/	/	46. Balance piston leakage rates					
/	/	/	47. When specified, vendor shall supply curves of balance piston line differential pressure vs thrust load					
/	/	/	48. Production/delivery schedule					
/	/	/	49. Testing procedures					
/	/	/	50. Progress reports					
/	/	/	51. Installation manual					
/	/	/	52. Operating and maintenance manual					
/	/	/	53. Technical data manual					

Distribution Record

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

CENTRIFUGAL AND AXIAL COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

1. Where necessary to meet the scheduled shipping date, the vendor shall proceed with manufacture upon receipt of the order and without awaiting the purchaser's approval of drawings.
2. The vendor shall send all drawings and data to the following:

   ____

   ____

   ____

3. All drawings and data shall show project, purchase order, and item numbers as well as plant location and unit. One set of the drawings and instructions necessary for field installation, in addition to the copies specified above, shall be forwarded with shipment.
4. See the descriptions of required items that follow.
5. All of the information indicated on the distribution schedule shall be received before final payment is made.
6. If typical drawings, schematics, and bills of material are used for proposals, they shall be marked up to show the expected weight and dimensions to reflect the actual equipment and scope proposed.

Nomenclature:

S number of weeks before shipment

F number of weeks after firm order

D number of weeks after receipt of approved drawings

Vendor ____

Date________________ Vendor Reference ____________________________

Signature____

(Signature acknowledges receipt of all instructions)

B.2 Descriptions

1) Vendor-certified dimensional outline drawing and list of connections, including the following:
    a) the size, rating, and location of all customer connections;
    b) approximate overall and handling weights;
    c) overall dimensions and maintenance and dismantling clearances;
    d) shaft centerline height;
    e) dimensions of baseplate (if furnished) for train or skid mounted package, complete with diameters, number, and locations of bolt holes and thicknesses of sections through which the bolts pass;
    f) grounding details;
    g) forces and moments allowed for suction and discharge nozzles;
    h) center of gravity and lifting points;
    i) shaft end separation and alignment data;
    j) direction of rotation;
    k) winterization, tropicalization, and/or noise attenuation details, when required;
    l) sketches to show lifting of assembled machine and major components and auxiliaries.
2) Cross-sectional drawings and part numbers of major equipment.
3) Rotor assembly drawings and part numbers.
4) Thrust-bearing assembly drawings and part numbers.
5) Journal-bearing assembly drawings and bill of materials.
6) Coupling assembly drawing and bill of materials.
7) Lube-oil schematic and bill of materials, including the following:
    a) oil flows, temperatures, and pressure at each point;
    b) control alarm shutdown settings for pressure and temperature;
    c) total heat loads;
    d) utility requirements, including electrical, water, air, and steam;
    e) pipe, valve, and orifice sizes;
    f) instrumentation, safety devices, control schemes, and wiring diagrams.
8) Lube-oil arrangement drawing and list of connections.
9) Lube-oil component drawings and data, including the following:
    a) pumps and drivers;
    b) heat exchangers, filter, and reservoir;
    c) instrumentation.

10) Seal system schematic and bill of materials, including the following:

    a) flows oil or gas, temperatures, and pressures at each point;

    b) control, alarm, and shutdown settings for pressure and temperatures;

    c) total heat load for heat exchangers, if required;

    d) utility requirements, including electrical, water, air, and steam;

    e) pipe, valve, and orifice sizes;

    f) instrumentation, safety devices, control schemes, and wiring diagrams;

    g) filtration requirements;

    h) height of overhead tank above centerline of machine.

11) Seal system arrangement drawing and list of connections.

12) Seal system components drawing and data, including the following:

    a) pumps and drivers;

    b) heat exchangers, filter, and reservoirs;

    c) instrumentation.

13) Seal assembly drawing and part numbers.

14) Electrical and instrumentation arrangement drawing and list of connections:

    a) vibration warning and shutdown limits;

    b) bearing temperature warning and shutdown limits;

    c) lube-oil temperature warning and shutdown limits;

    d) lube-oil pressure warning and shutdown limits;

    e) lube-oil level warning and shutdown limits;

    f) machine discharge pressure and temperature warning and shutdown limits;

    g) seal, pressure, temperature, flow warning, and shutdown limits.

15) Electrical and instrumentation arrangement drawing and list of connections.

16) Buffer gas system schematic and bill of materials.

17) Buffer gas system arrangement drawing and list of connections

18) Buffer gas system component drawings and data, including the following:

    a) control devices;

    b) pressure and filtration requirements.

19) Datasheets provided with proposal as-built.

20) Predicted noise level, sound pressure, and sound power level.

21) Metallurgy of major components identified with ASTM, AISI, ASME, or SAE numbers stated in proposal.

22) Lateral analysis report when required shall also include a stability analysis.

23) Torsional analysis report.

24) Vibration analysis conducted on machines that require disassembly after balancing to allow machine assembly. The vendor shall also provide historical unbalance data for the machine size and type.

25) Performance data and curves, sufficient performance data to enable the purchaser to properly design a control system, and surge prevention.

26) Dimensions taken from each impeller before and after overspeed testing shall be submitted for review.

27) Mechanical running test report to include the following:

    a) unfiltered vibration;

    b) plots showing synchronous vibration and phase angle, filtered and unfiltered;

    c) when specified, data shall be furnished in polar form;

    d) when specified, tape recordings shall be made of all real time vibration data;

    e) electrical and mechanical runout at each probe.

    Immediately upon completion of each witnessed mechanical or performance test, copies of the log and data recorded during the test shall be given to the witnesses.

28) Coupling selection and rating.

29) List of spare parts recommended for start-up and normal maintenance purposes.

30) List of the special tools furnished for maintenance.

31) The vendor shall provide the purchaser with instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

32) A description of any special weather protection required for start-up, operation, and period of idleness under the site conditions specified on the datasheets.

33) A complete list of utility requirements: quantity, filtration, and supply pressure of the following:

    a) steam;

    b) water;

    c) electricity;

    d) air;

    e) gas;

    f) lube oil and seal oil (quantity and supply pressure);

    g) heat loads;

    h) power ratings and operating power requirements for auxiliary drivers.

34) A list of machines similar to the proposed machines that have been installed and operating under conditions analogous to those specified in the inquiry.

35) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment, including any unacceptable speeds due to natural frequencies.

36) A list of any components that can be construed as being of alternative design, requiring purchaser's acceptance.

37) A summary of the materials of construction for the compressor, including hardness for materials exposed to H_2S.

38) The maximum seal gas rates (injection or eduction) and rated or expected inner seal-oil leakage rates, if applicable. When self-acting dry gas seals are supplied, expected seal gas consumption, minimum seal gas supply flow, and primary vent flow should be given at maximum sealing pressure and at conditions over the operating envelope of the machine.

39) When interstage heat exchangers are furnished, the vendor shall provide the following:

    a) drawing showing cooling system details;

    b) data for purchaser heat and material balances;

    c) details of provisions for separating and withdrawing condensate;

    d) vendor's recommendations regarding provision for support and piping expansion.

40) Drawings, details, and descriptions of the operations of instrumentation and controls, as well as the makes, materials, and type of auxiliary equipment. The vendor shall also include a complete description of the alarm and shutdown facilities to be provided.

41) The minimum length of straight pipe required for proper flow characteristics at the inlet and at any side inlet connection.

42) Maximum and minimum allowable seal pressure for each compressor.

43) A statement of the manufacturer's capability regarding testing (including performance testing) of the compressor and any other specified items on the train. Details of each optional test specified shall be included.

44) Performance curves shall be submitted for each section (between purchaser's process nozzles) of each casing as well as an overall curve for the train. All curves submitted prior to complete performance testing shall be marked "predicted."

    a) Any set of curves resulting from a test shall be marked "tested."

    b) If a performance test is specified, the supplier shall provide test data and curves when the test has been completed. The surge points shall be shown on the performance curves.

45) For compressors that have a back-to-back impeller arrangement, the supplier shall furnish a curve showing the expected loading on the active or inactive side of the thrust bearing vs any combination of differential pressures across the low-pressure and high-pressure sections of the casing.

46) The vendor shall supply balance piston leakage based on design clearances and twice design clearances for the rated conditions.

47) If specified, the vendor shall supply curves of balance piston line differential pressure vs thrust load.

48) The vendor shall provide production and delivery schedules.

49) The vendor shall submit detailed procedures including acceptance criteria for the mechanical running test and all optional tests, at least 6 weeks prior to the first running test.

50) The vendor shall submit progress reports.

51) All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of final certified drawings.

52) A manual containing all required operating and maintenance instructions shall be supplied not later than 2 weeks after all specified test shall have been successfully completed.

53) The vendor shall provide a "technical data manual within 30 days of completion" of shop testing, including the following:

    a) necessary certification of materials;

    b) purchase specification for all items on the bill of materials;

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

    d) heat treat records;

    e) results of quality test and inspections;

    f) mechanical running test data log;

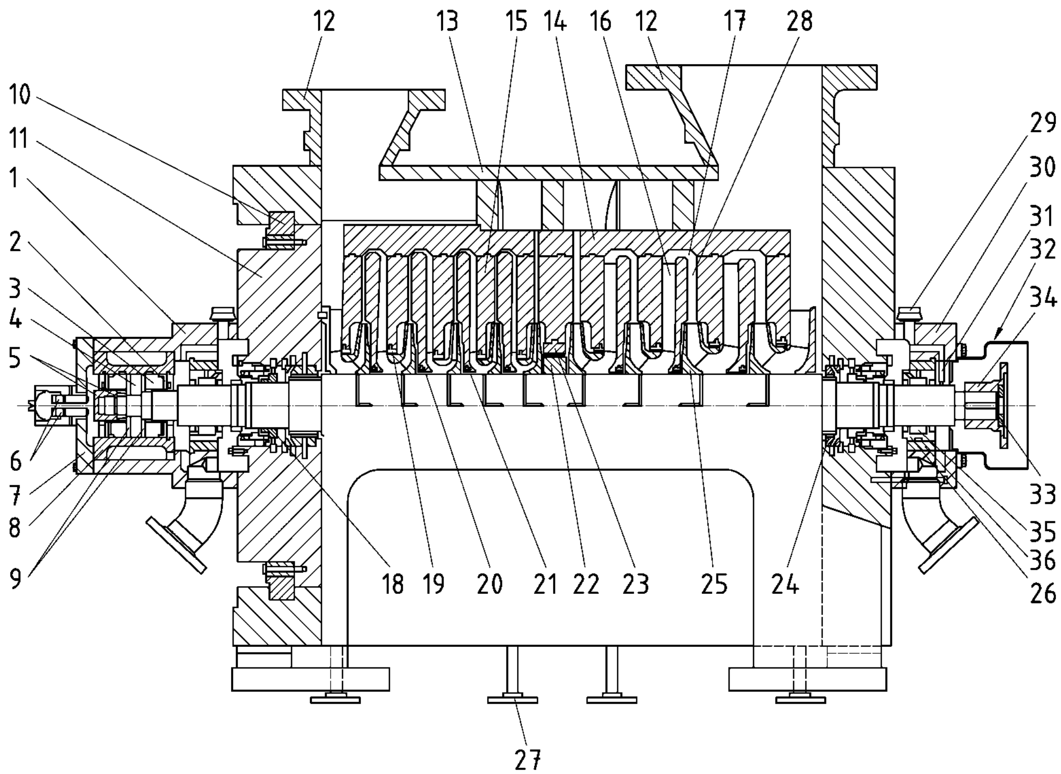
    g) final assembly maintenance and running clearances.

    The vendor is also required to keep these data available for examination by the purchaser upon request, for at least 5 years.

Annex C
(informative)

Centrifugal Compressor Nomenclature

Figure C.1 illustrates nomenclature of key parts of a typical nonintegrally geared centrifugal compressor (Barrel Type).



NOTE Some compressors will use bolted-head construction.

Key

1	bearing housing	10	shear ring	19	impeller-eye labyrinth	28	diffuser passage
2	thrust shims	11	end head	20	shaft sleeve	29	breather/vent
3	thrust base ring	12	main process connections	21	diaphragm labyrinth	30	bearing housing
4	thrust collar	13	casing	22	balance piston	31	radial vibration probe
5	thrust collar locknuts	14	inner barrel	23	balance piston labyrinth	32	coupling guard
6	axial-position probes	15	diaphragm	24	labyrinth seal	33	coupling locknut
7	end cover	16	return channel	25	impeller	34	coupling hub
8	thrust-bearing carrier	17	crossover	26	journal-bearing housing	35	journal-bearing shoes
9	thrust-bearing shoes	18	end seal	27	case drains	36	journal-bearing carrier

Figure C.1—Centrifugal Compressor Nomenclature

Annex D
(informative)

Inspector's Checklist

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
6.2 MATERIALS					
Coating applied prior to acceptance balance	6.2.2.1	1			
PMI	6.2.3.1	1			
Impact testing	6.2.4.3	1			
Castings—material specification compliance	6.2.5.1	1			
Castings—purchaser approval of repairs	6.2.5.5.5	1			
Castings—ductile (nodular) iron	6.2.5.7	1			
Forgings—repairs	6.2.6.2	1			
Welding—nonpressure components	6.2.7.1	1			
Welding—pressure-containing and rotating parts	6.2.7.2	1			
6.3 CASINGS					
Jackscrews, dowels, and special tools	6.3.1.5	1			
Depth of threaded holes	6.3.1.6.2	1			
Studs instead of cap screws	6.3.1.8.3	1			
Adequate clearance at bolts	6.3.1.8.4	1			
Bolting materials	6.3.1.8.8	1			
Welding	6.3.1.9	1			
Casing repair—minimum level of inspection and purchaser review	6.3.2.1	1			
Casing repair—major repairs	6.3.2.4.1	1			
Casing repair—material standards	6.3.2.5	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Pressure casings—plate edges	6.3.2.6.1	1			
Pressure casings—MPT or LPT	6.3.2.6.2	1			
Pressure casings—weld QC	6.3.2.6.3	1			
Pressure casings—full penetration welds	6.3.2.6.4	1			
Casings—heat treatment	6.3.2.6.5	1			
Pressure-containing weld inspection	6.3.2.6.6	1			
Materials inspection standards	6.3.3.3	1			
Cast steel casings—acceptability of defects	6.3.3.4	1			
Pressure casing connection size	6.4.1.4	1			
Casing connections—welding before hydro test	6.4.1.7	1			
Main process connection orientation	6.4.2.1	1			
Flanges	6.4.2.2	1			
Cast iron flanges	6.4.2.9	1			
Concentricity of bolt circle and bore	6.4.2.13	1			
Steel flange facing finish	6.4.2.14	1			
Machined and studded connections	6.4.2.15	1			
Flanges parallel within 0.5 degrees	6.4.2.17	1			
Auxiliary connections—flanges	6.4.3.2	1			
Auxiliary connections—allowable types	6.4.3.3	1			
Auxiliary connections—pipe nipples	6.4.3.6	1			
Auxiliary connections—socket weld gap	6.4.3.7	1			
Auxiliary connections—lube or seal service	6.4.3.4	1			
Threaded openings for tapered pipe threads	6.4.4.1	1			
Tapered pipe threads	6.4.4.2	1			
Seal welding tapered pipe threads	6.4.4.3	1			
Pipe nipples for threaded openings	6.4.4.4	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Plugs for threaded openings	6.4.4.5	1			
Machine mounting surfaces	6.5.1	1			
6.6 ROTATING ELEMENTS					
Shaft ends for couplings	6.6.1.1	1			
Assembled rotor marking	6.6.1.1	2			
Shaft sensing areas for probes	6.6.1.2	1			
Shaft sensing areas—final surface finish	6.6.1.3	1			
Stud or tie-bolt proof load testing	6.6.2.2.1.2	2			
Modular rotor wet MPT or fluorescent LPT	6.6.2.2.2	2			
Thrust collar surface finish and TIR	6.6.1.6	1			
Axial compressor blade peening	6.6.5.4	2			
Fabricated impeller inspection	6.6.2.3	1			
Cast impeller inspection	6.6.2.4	1			
Cast impeller repair	6.6.2.5	1			
Welding not permitted for impeller balancing	6.6.2.6	1			
MPT or LPT of impellers after overspeed	6.6.2.7	1			
6.8 DYNAMICS					
Confirmation of critical speeds	6.8.3.1.9	1			
Unbalanced rotor response verification test	6.8.3	1			
Additional testing	6.8.3.2	1			
Rotating element—component balance	6.8.7.1	1			
Rotating element—sequential multiplane balance	6.8.7.6	1			
Rotating element—if disassembled after balance	6.8.7.7	1			
Rotating element—reassembly check balance	6.8.7.7	1			
Operating speed balance	6.8.7.9	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Operating speed balance procedure	6.8.8	1			
6.9.3 NAMEPLATES AND ROTATION ARROWS					
Nameplate at readily visible location	6.9.3.1	1			
Nameplate material	6.9.3.2	1			
Nameplate contents	6.9.3.2	2			
Rotation arrows	6.9.3.3	2			
Lateral critical speeds on nameplate	6.9.3.6	1			
7.2 SOLEPLATES AND BASEPLATES					
Jackscrews	7.2.1.2.1	1			
Alignment shims	7.2.1.2.2	1			
Machinery mounting surfaces	7.2.1.2.3	1			
Anchor bolt clearance	7.2.1.2.8	1			
Vertical leveling screws	7.2.1.2.9	1			
Radiused corners for grout	7.2.1.2.10	1			
Hold-down bolt clearance	7.2.1.2.13	1			
Wrench clearance	7.2.1.2.13	1			
Grout contacting surface preparation	7.2.1.2.16	1			
Mounting surface preservation	7.2.1.2.18	1			
Seal welded joints	7.2.2.3	1			
Leveling pads or targets	7.2.2.8	1			
Additional pads or targets	7.2.2.8.2	1			
Lifting lugs	7.2.2.9.1	1			
Grout fill and vent holes	7.2.2.10.1	1			
Soleplate thickness	7.2.3.2	1			
Soleplate size	7.2.3.3	1			
Soleplates fully machined	7.2.3.5	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Subsoleplates	7.2.3.6	1			
7.3 CONTROLS AND INSTRUMENTATION					
Controls ingress protection level	7.3.1.4	1			
Terminal box ingress protection level	7.3.1.5	1			
Conduit and cable location and installation	7.3.1.8	1			
Transducers and sensors per API 670	7.3.7.1	2			
Monitors per API 670	7.3.7.2	2			
Bearing temperature monitor per API 670	7.3.7.4	2			
Casing vibration transducers per API 670	7.3.7.5	2			
Casing vibration monitors per API 670	7.3.7.6	2			
7.4 SPECIAL TOOLS					
Use of tools	7.4.3	1			
Tool packing and marking	7.4.4	1			
7.8.1 PIPING AND APPURTENANCES					
Breakout spools	7.8.1.1.3	1			
Provisions to bypass bearings	7.8.1.1.4	1			
Provisions to bypass dry gas seals	7.8.1.1.5	1			
Instrument piping	7.8.1.2	1			
Process piping	7.8.1.3	1			
8.1 INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT—GENERAL					
Access to vendor's quality control program	8.1.8	1			
8.2 INSPECTION					
Painting before hydro test	8.2.1.2	1			
Cleanliness	8.2.1.5	1			
Hardness of parts, welds, and heat-affected zones	8.2.1.7	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Radiographic inspection	8.2.3	1			
Ultrasonic inspection	8.2.4	1			
Magnetic particle inspection	8.2.5	1			
Liquid penetrant inspection	8.2.6	1			
8.3 TESTING					
Contract probes and accelerometers used	8.3.5.1	1			
Contract shaft seals and bearings used	8.3.2.1.1	2			
Oil system cleanliness before testing	8.3.2.1.5	2			
Joint and connection tightness	8.3.5.6	1 2			
Warning, protective, and control devices	8.3.5.7	1 2			
Contract coupling	8.3.2.1.6	2			
Coupling hub location marked	8.3.2.1.7	2			
Instrument calibration	8.3.5.8	1			
Hydrostatic test—pressure	8.3.2.1	1			
Hydrostatic test—duration	8.3.2.3	1			
Hydrostatic test—chloride content	8.3.2.4	1			
Impeller overspeed test	8.3.3	1			
Residual magnetism	6.3.1.11, 6.6.1.4, 6.7.4.8	1			
Dry gas seals	8.3.4	1			
Mechanical running test—operation of equipment and test instrumentation	8.3.5.10.1	1			
Mechanical running test—unfiltered vibration	8.3.5.10.2	1			
Mechanical running test—vibration plots	8.3.5.10.3	1			
Mechanical running test—real-time vibration data recorded	8.3.5.10.5	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Mechanical running test—seal flow data	8.3.5.10.6	1			
Mechanical running test—lube oil and seal oil variations	8.3.5.10.7	1			
Mechanical running test—hydrodynamic bearing inspection	8.3.5.11.1	1			
Mechanical running test—shaft end seal inspection	8.3.5.12	1			
Gas test after hydro test	8.3.7.3	1			
Assembled compressor gas leak test	8.3.3	2			
Sound-level test	8.3.7.4	1			
Auxiliary-equipment test	8.3.7.5	1			
Post-test inspection of internals	8.3.7.6	1			
Full-load/full-pressure/full-speed test	8.3.7.7	1			
Post-test inspection of coupling fit	8.3.7.8	1			
Spare-parts test	8.3.7.9	1			
8.4 PREPARATION FOR SHIPMENT					
Preparation for shipment	8.4.1	1			
Dry gas seals removed for shipment	8.4.2	2			
Testing completed and equipment released	8.4.3	1			
Coating on exterior surfaces	8.4.3.1.1	1			
Exterior machined surfaces coating	8.4.3.2	1			
Interior of equipment	8.4.3.3	1			
Internal surfaces of bearing housings	8.4.3.5	1			
Flange covers	8.4.3.6	1			
Threaded openings	8.4.3.7	1			
Beveled welding openings	8.4.3.8	1			
Lifting point identification	8.4.3.9	1			

Item (Inspector's Checklist Part 2)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Equipment tagging and packing lists	8.4.3.11	1			
Spare rotor storage preparation	8.4.3.12	1			
Spare rotor container	8.4.3.12.3	1			
Cradle support liner	8.4.3.13	1			
Rotor preparation for vertical storage	8.4.3.12.4	1			
Fit-up and assembly of piping and heat exchangers	8.4.3.14	1			
Shaft and coupling protection	8.4.3.15	1			
Auxiliary connection marking	8.4.4	1			
Auxiliary piping match marks	8.4.6	1			
IOM shipped with equipment	8.4.7	1			
Wood used in export shipping	8.4.8	1			

Annex E
(normative)

Nozzle Forces and Moments

E.1 General

E.1.1 The April 1988, November 1979, and October 1973 issues of API 617 referred nozzle forces and moments calculations to appropriate NEMA documents with the stipulation that the constants in the equations be multiplied by 1.85. Experience has shown that there has not been a uniform interpretation of "1.85 times NEMA." Therefore, the equations have been adapted to compressors by identifying all the constants and clarifying that the equivalent of the exhaust nozzle in the NEMA calculation is the largest compressor nozzle. This is usually, but not necessarily, the inlet nozzle.

E.1.2 For machinery primarily designed for low pressures (such as axial compressors, low-pressure overhung compressors, or compressors or machinery designed with open impellers that rely upon close radial and axial clearances of the impeller to the casing), the vendor shall identify the maximum allowable forces and moments.

E.2 Equations

The design of each compressor body shall allow for limited piping loads on the various casing nozzles. For maximum system reliability, nozzle loads imposed by piping should be as low as possible regardless of the compressor's (machines') load-carrying capability. As a standard, for cast axially split centrifugal compressors, radially split centrifugal compressors and higher pressure, over 50 psig inlet pressure, overhung single-stage compressors the forces and moments acting on compressors due to the inlet, side stream, and discharge connections should be limited by the following.

The total resultant force and total resultant moment imposed on the compressor at any connection should not exceed the values shown in Equation (E.1).

In SI units:

$$F_r + 1.09\,M_r \le 54.1\,D_e \tag{E.1a}$$

In USC units:

$$3\,F_r + M_r \le 927\,D_e \tag{E.1b}$$

where

F_r is the resultant force, newtons (lb) (see Figure E.1);

$$F_r = \sqrt{F_x^2 + F_y^2 + F_z^2} \tag{E.2}$$

M_r resultant moment, in newton-meters (ft-lb) from Figure E.1;

$$M_r = \sqrt{M_x^2 + M_y^2 + M_z^2} \tag{E.3}$$

For sizes up to 200 mm (8 in.) in diameter:

D_e is the nominal pipe diameter of the connection, mm (in.).

For sizes greater than 200 mm (8 in.), use the following values.

In SI units:

$$D_e = \frac{(400 + D_{nom})}{3} \text{ (mm)} \quad \text{(E.4a)}$$

In USC units:

$$D_e = \frac{(16 + D_{nom})}{3} \text{ (in.)} \quad \text{(E.4b)}$$

where

D_e is the equivalent pipe diameter of the connection, mm (in.);

D_{nom} is the nominal pipe diameter, mm (in.).

The combined resultants of the forces and moments of the inlet, side stream, and discharge connections resolved at the centerlines of the largest connection should not exceed the following.

The resultants shall not exceed the following.

In SI units:

$$F_c + 1.64M_c \leq 40.4D_c \quad \text{(E.5a)}$$

In USC units:

$$2F_c + M_c \leq 462D_c \quad \text{(E.5b)}$$

where

F_c is the combined resultant of inlet, side stream, and discharge forces, newtons (lb);

M_c is the combined resultant of inlet, side stream, and discharge moments, and moments resulting from forces, newton-meters (ft-lb);

D_c is the diameter [mm (in.)] of one circular opening equal to the total areas of the inlet, side stream, and discharge openings. If the equivalent nozzle diameter is greater than 230 mm (9 in.), use a value of D_c equal to the following.

In SI units:

$$D_c \frac{(460 + \text{Equivalent Diameter})}{3} \text{ (mm)} \quad \text{(E.6a)}$$

In USC units:

$$D_c \frac{(18 + \text{Equivalent Diameter})}{3} \text{ (in.)} \quad \text{(E.6b)}$$

The absolute value of the individual components (see Figure E.1) of these resultants should not exceed the following.

In SI units:

$$F_x = 16.1D_c \qquad M_x = 24.6D_c$$
$$F_y = 40.5D_c \qquad M_y = 12.3D_c \tag{E.7a}$$
$$F_z = 32.4D_c \qquad M_z = 12.3D_c$$

In USC units:

$$F_x = 92D_c \qquad M_x = 462D_c$$
$$F_y = 231D_c \qquad M_y = 231D_c \tag{E.7b}$$
$$F_z = 185D_c \qquad M_z = 231D_c$$

where

F_x is the horizontal component of F_c, parallel to the compressor shaft, newtons (lb);

F_y is the vertical component of F_c, newtons (lb);

F_z is the horizontal component of F_c at right angles to be compressor shaft, newtons (lb);

M_x is the component of M_c, around the horizontal axis, newton-meters (ft-lb);

M_y is the component of M_c, around the vertical axis, newton-meters (ft-lb);

M_z is the component of M_c around the horizontal axis at right angles to the compressor shaft, newton-meters (ft-lb).

These values of allowable forces and moments pertain to the compressor structure only. They do not pertain to the forces and moments in the connecting pipes, flanges, and flange bolting, which should not exceed the allowable stress as defined by applicable codes and regulatory bodies.

It is recommended that calculated operating loads be minimized by appropriate piping system design. If the forces and moments limits of this annex cannot be achieved, after all efforts have been made to modify the piping design system, the final calculated forces and moments shall be identified to the vendor. The final magnitude of the forces and moments shall be agreed.

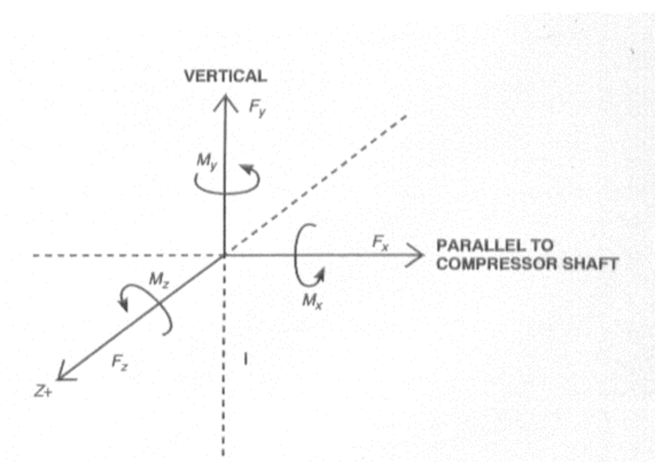


Figure E.1—Combined Resultants of the Forces and Moments of Corrections

Axial and Centrifugal Compressors and Expander-compressors
Part 3—Integrally Geared Centrifugal Compressors

1 Scope

API 617, Part 3 specifies integrally geared centrifugal compressors in conjunction with API 617, Part 1.

NOTE 1 See API 672 for packaged plant instrument air compressors.

NOTE 2 Expander stages are sometimes provided on these machines.

2 Normative References

Referenced documents indispensable for the application of this document are listed in Section 2 of Part 1.

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

For the purposes of this document, the terms, definitions, acronyms, abbreviations, and symbols given in Part 1 apply.

NOTE A cross-section showing nomenclature of an integrally geared centrifugal compressor can be found in Annex C.

4 Dimensions and Units

The dimensional and unit requirements of Part 1 shall apply.

5 Requirements

5.1 Statutory Requirements

The statutory requirements of Part 1 shall apply.

5.2 Unit Responsibility

The unit responsibilities of Part 1 shall apply.

6 Basic Design

6.1 General

6.1.1 Performance

6.1.1.1 The sectional head-capacity characteristic curve of each compressor section shall rise continuously from the rated point to predicted surge.

6.1.1.2 For any speed, the minimum operating capacity of the compressor, without the use of a bypass (e.g. recycle valve), shall be either the capacity at the anti-surge control line or 10 % greater than the predicted surge capacity shown in the proposal.

6.1.2 Lubricants

6.1.2.1 The design lubricant shall be hydrocarbon oil of viscosity Grade 32 with an FZG load stage of 6.

6.1.2.1.1 Viscosity Grade 46 with an FZG load stage 6 may be used as a design lubricant, with purchaser's approval.

6.1.2.1.2 Oils with extreme pressure additives shall not be used.

NOTE Typical oil used in refineries and chemical plants has an FZG of 5 or higher. Requiring a higher FZG by design can require the need for special oil for this equipment.

6.2 Materials

Materials shall be in accordance with 6.2 of Part 1.

NOTE Refer to Annex F of Part 1 for typical materials.

6.3 Casings

6.3.1 General

Casings shall be in accordance with 6.3 of Part 1 and 6.3.2 through 6.5, as follows.

6.3.2 Pressure-containing Casings

6.3.2.1 The maximum allowable working pressure (MAWP) of each pressure casing shall be at least equal to the specified relief valve set pressure for that casing.

6.3.2.2 [●] The purchaser will specify the relief valve set pressure(s) for final discharge pressure and intermediate casing pressures, if applicable.

NOTE If only one relief valve pressure is specified, its set pressure will not usually apply to the intermediate pressure.

6.3.2.3 When a relief valve set pressure is not specified, each pressure casing shall be rated for at least 125 % of the maximum specified discharge pressure (gauge) of that pressure casing as determined by the supplier.

6.3.2.4 Overpressure protection shall be furnished by the purchaser.

6.3.2.5 Socket-head or spanner-type bolting shall not be used externally unless specifically approved by the purchaser. For limited space locations, integrally flanged fasteners may be required.

6.3.2.6 Casing repairs shall be in accordance with 6.3.2 of Part 1.

6.3.2.7 Casing material inspection of pressure-containing parts shall be in accordance with 6.3.3 of Part 1.

6.4 Pressure Casing Connections

6.4.1 General

Pressure casing connections shall be in accordance with 6.4 of Part 1 and the following paragraphs.

6.4.2 Main Process Connections

Main process connections shall be in accordance with 6.4.2 of Part 1.

6.4.3 Auxiliary Connections

6.4.3.1 If flanged or machined and studded openings are impractical, threaded connections may be used where they do not come in contact with flammable or toxic gas, with purchaser's approval as follows:

a) on nonweldable materials, such as cast iron;

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

6.4.3.2 These threaded openings shall be as specified in 6.4.4 of Part 1.

6.4.3.3 Auxiliary connections shall be at least DN 20 (NPS $^3/_4$ in.). See 6.9.2.10 through 6.9.2.12 and Table 1 for auxiliary gearbox connections.

NOTE See 6.4.1.4 and 6.4.1.5 of Part 1 for allowable connection sizes.

6.4.3.4 Threaded connections for pipe sizes DN 20 (NPS $^3/_4$ in.) through DN 40 (NPS 1 $^1/_2$ in.) size are permissible with the approval of the purchaser.

NOTE See 6.4.1.4 and 6.4.1.5 of Part 1 for allowable connection sizes.

6.5 Stationary Components

6.5.1 Casing Support Structure

6.5.1.1 The mounting of the pressure casing (volute) to the gearbox shall be per 6.5.1 of Part 1.

6.5.1.2 Bolting used to mount pressure casings shall be per 6.3.1.8 of Part 1.

6.5.2 External Forces and Moments

6.5.2.1 The supplier shall furnish the allowable forces and moments for each main process nozzle that has a customer connection in tabular form with the proposal.

6.5.2.2 Allowable nozzle loadings shall be per Annex E.

NOTE Piping system design will need to be rigorous in order to avoid piping expansion joints.

6.5.3 Pressure casing and supports shall be designed to have sufficient strength and rigidity to avoid adversely affecting impeller running clearances, gear contact pattern, seals, bearings, and coupling alignment.

6.5.4 Variable Inlet and/or Diffuser Guide Vanes

6.5.4.1 [●] Variable guide vanes shall be provided when specified or required by the supplier to meet specified operating conditions.

6.5.4.2 When provided, variable inlet guide vanes and operating mechanisms shall be suitable for all specified operating conditions, as well as start-up, shutdown, trip-out, settle-out, and momentary surge.

6.5.4.2.1 Guide vanes shall be mounted in replaceable bushings. Vanes may be positioned in the housing by replaceable permanently sealed rolling element bearings, if approved by the purchaser.

6.5.4.2.2 If variable guide vanes are used for toxic, flammable, or explosive process gas, then the linkage passing through the casing or enclosure shall be sealed to prevent leakage.

6.5.4.2.3 The vane foils shall have an aerodynamically smooth surface, especially where the shank enters the gas stream through the housing. A cantilevered design in lieu of a center supported vane design is preferred.

6.5.4.2.4 [●] The vane position on loss of the control signal shall be agreed between the supplier and the purchaser.

6.5.4.2.5 A vane control system consisting of a valve positioner with direct driven local position indicator shall be provided that will be visible during operation of the machine.

6.5.4.2.6 [●] Additional components to the vane control system in 6.5.4.2.5 shall be as specified.

6.5.4.3 [●] If specified, the actuator seal shall be buffered using a barrier gas.

6.6 Rotating Elements

6.6.1 General

6.6.1.1 Each impeller and shaft shall be clearly marked with a unique identification number on an accessible area that is not prone to maintenance damage.

6.6.1.2 Unless other shaft protection is approved by the purchaser, replaceable components shall be furnished at close clearance points.

6.6.1.3 Sleeves, spacers, or bushings shall be made of materials that are corrosion-resistant in the specified service (see 6.2.1 of Part 1 for limitations).

6.6.1.4 Shaft sleeves shall be provided under shaft end seals.

6.6.1.5 Sleeves shall be treated to resist wear and sealed to prevent gas leakage between the shaft and sleeve.

6.6.2 Impellers

Refer to 6.6.2 of Part 1 for impeller requirements.

6.6.3 Thrust Balancing

6.6.3.1 Thrust loads from impellers and gears shall be absorbed by individual thrust bearings on pinions or transmitted to the bull gear thrust bearing by means of thrust rider rings fixed to the pinions and bull gear.

6.6.3.2 All specified operating conditions and start-up conditions shall be evaluated for residual thrust loads.

6.6.3.3 Thrust bearings shall be used on pinions with dry gas seals.

6.6.3.4 Use of thrust rider rings on the bull and pinion gears with dry gas seals requires purchaser's approval.

NOTE Dry gas seals are prone to premature failure in the presence of excessive axial motions and vibrations. Refer to 7.4.7.2 and 7.4.7.3 for axial displacement and vibration monitoring.

6.7 Bearings and Bearing Housings

6.7.1 General

6.7.1.1 Refer to 6.7 of Part 1 and the following sections for bearing and bearing housing requirements.

6.7.1.2 Radial and thrust bearings shall be of the hydrodynamic fluid film type.

6.7.1.3 Thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API 670.

6.7.1.3.1 The predicted bearing metal temperature at maximum operating bearing load and rated speed shall be a maximum of 95 °C (200 °F), with a maximum inlet oil temperature of 50 °C (120 °F) and with the specified nominal lube oil inlet pressure.

6.7.1.3.2 When the above criteria cannot be met, purchaser and supplier shall agree on acceptable bearing metal temperatures.

6.7.1.3.3 The manufacturer shall provide, in the test procedure, the predicted bearing metal temperature at the mechanical run test conditions.

6.7.1.3.4 If the measured bearing metal temperature during the mechanical run test at the manufacturer's test stand exceeds this predicted temperature, the purchaser and the supplier shall agree on requirements for any additional testing and on the gear unit's suitability for shipment.

NOTE Mechanical run tests at the gear supplier's shop are typically conducted at no-load or low-load conditions. The bearing metal temperature during these tests will typically be less than the predicted temperature at rated load and rated speed.

6.7.1.4 The minimum predicted film thickness for any operating condition shall not be less than 20 µm (0.0008 in.).

6.7.1.5 For radial bearings, the maximum allowable bearing L/D will be 1.0.

6.7.2 Hydrodynamic Radial Bearings

6.7.2.1 Sleeve or pad radial bearings shall be used and shall be split for ease of assembly. The use of nonsplit designs requires the purchaser's approval.

6.7.2.2 The bearings shall be precision bored with steel, copper, cupro-nickel or bronze backed babbitted liners, pads, or shells.

6.7.2.3 The bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

6.7.2.4 Bearing liners, pads, or shells shall be in axially split housings.

6.7.2.5 The bearing design shall not require removal of the coupling hub to permit replacement of the bearing liners, pads, or shells unless approved by the purchaser.

6.7.3 Hydrodynamic Thrust Bearings

6.7.3.1 Thrust bearings shall be steel-backed, babbitted multiple-segment type, designed for thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Thrust bearings may be fixed geometry (e.g. tapered-land) or tilting-pad type and may exceed the 50 % of the bearing manufacturer's ultimate load rating.

NOTE See 6.6.3 for discussion on thrust rider rings or thrust surfaces mounted on pinions and/or bull gears..

6.7.3.2 [●] If specified, thrust bearings shall be tilting pad on one or both sides.

6.7.3.3 [●] If specified or with purchaser's approval, thrust bearings pads shall be copper-alloy backed.

6.7.4 Bearing Housings

6.7.4.1 The term "bearing housing" refers to all bearing enclosures including the gearbox.

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

6.8 Dynamics

Refer to Part 1 for dynamics requirements.

NOTE Operating speed balance of pinions is not practical and is rarely done.

6.9 Other Standard Specific Components

6.9.1 Shaft End Seals

6.9.1.1 Process seals and seal systems shall be in accordance with 6.9.1 of Part 1.

NOTE Equipment covered in this part can be available with any of the shaft end seal types covered in Part 1. Additional hybrid types are available.

6.9.1.2 [●] The purchaser shall specify the type of shaft end seal(s) to be provided and all operating conditions including start-up, shutdown, and settle-out conditions.

6.9.2 Integral Gearing

6.9.2.1 The supplier shall dowel or key the gearbox to the soleplate or baseplate to maintain alignment.

6.9.2.2 Gearboxes shall be designed with internal oil passages to minimize external piping.

6.9.2.2.1 Supplier shall not use additional internal orifices as part of the internal oil passages. This does not include the metering provisions in bearings and spray nozzles.

6.9.2.3 External piping connections shall conform to the requirements of 6.4.3 of Part 1.

6.9.2.4 The design of internal piping and tubing shall achieve proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.

6.9.2.5 Cantilevered piping in excess of 10 pipe diameters shall include reinforcing gussets in two planes at all pipe-to-flange connections.

6.9.2.6 The gearbox shall be designed to permit rapid drainage of lube oil and to minimize oil foaming (which could lead to excessive heating of the oil).

NOTE For gears with pitch line velocities of more than 125 m/s (25,000 ft/min), design features such as windage baffles, false bottoms, adequate sump depth, and an additional full-size drain connection should be considered.

6.9.2.7 A removable and gasketed inspection cover or covers shall be provided in the gearbox to permit direct visual inspection of the full-face width of the pinion(s) and gear.

6.9.2.8 The inspection opening or openings shall be at least one-half the width of the gear face.

6.9.2.9 Permanent coatings or paint shall not be applied to the interior of the casing, unless the purchaser approves in advance the material and method of application.

6.9.2.10 The drain pipe shall be sized to be no more than half full for a horizontal drain with a maximum velocity of 0.4 m/s (15 in./s).

6.9.2.10.1 A vertical (bottom) drain may be sized full, but with a maximum velocity of 0.2 m/s (7.5 in./s).

6.9.2.10.2 Both shall be based on the total inlet flow to the gear casing.

6.9.2.10.3 Table 1, shown below, outlines the typical drain pipe sizes and the associated maximum flow rates.

Table 1—Drain Pipe Sizes

Maximum Inlet Flow Rate		**Minimum Drain Pipe Size**	
Liters per minute	Gallons per minute	Millimeters [a]	Inches [a]
54	14	75	3
93	25	100	4
212	56	150	6
365	96	200	8
585	155	250	10
830	220	300	12
[a] Nominal pipe size.			

NOTE If the drain piping is not designed to ensure that it is never more than half full at any point, the gear unit cannot drain properly. Gear units with insufficient drainage can experience overheating, oil leakage, and potential damage.

6.9.2.11 Gearboxes shall be provided with a plugged or flanged-and-blinded purge gas connection.

6.9.2.12 Gearbox casing vents shall be designed to permit adequate draining, inhibit intrusion of dirt and moisture, and prevent the escape of oil mist to the atmosphere.

6.9.3 Gearbox Split Lines

6.9.3.1 Gearbox split lines shall use a metal-to-metal joint.

6.9.3.2 Adequate sealing shall be provided with a suitable joint compound or groove type seals.

6.9.3.3 Gaskets (including string type) shall not be used on the gearbox split lines.

6.9.4 Gear Rating

6.9.4.1 Refer to Annex F.

6.9.4.2 The rated power of the gearing shall not be less than the driver nameplate rating multiplied by the driver service factor.

6.9.4.3 When there are multiple pinions, the power rating of the gear sets shall not be less than:

a) 110 % of the maximum power transmitted by the gear set;

b) the maximum power of the driver (including service factor) prorated between all the gear sets, based on normal power demands; if the maximum transmitted torque occurs at a continuous operating speed other than the maximum continuous speed (N_{mc}), this torque and its corresponding speed shall be the basis for sizing the gear set.

6.9.4.4 The power rating based upon both pitting resistance and bending strength shall be calculated for each member of each gear set in the unit.

6.9.4.4.1 The pinion and bull gear teeth may have different ratings due to differences in material properties, geometry factors, and number of cycles under load.

6.9.4.4.2 The lowest of the four ratings (pinion bending, pinion pitting, bull gear bending, bull gear pitting) shall be used as the gear rating (see Annex F).

6.9.4.4.3 Gear sets shall be designed such that failure will occur due to pitting rather than bending (i.e. wear out before breaking).

NOTE Higher gear ratios require a large number of teeth; therefore, it is not always possible to provide tooth design which will fail in pitting rather than bending without compromising other aspects of the gear design (i.e. higher pitch line velocities).

6.9.4.4.4 Gearing shall be designed and manufactured to meet the requirements of ANSI/AGMA ISO 1328-1-B14 Grade 4.

6.9.4.4.5 The manufacturer shall provide documentation showing that the required quality levels in 6.9.4.4.4 have been met.

6.9.4.4.6 The pinion face width to working pitch diameter ratio (L/D ratio) shall be limited based on pinion tooth hardness, as follows.

6.9.4.4.6.1 For pinion hardness equal to or less than 38 Rc (BHN 354), L/D shall be limited to 2.0 maximum.

6.9.4.4.6.2 For pinion hardness equal to or greater than 58 Rc (BHN 615), L/D shall be limited to 1.6 maximum.

6.9.4.4.6.3 For pinion hardness between 38 and 58 Rc (BHN 354 and BHN 615), L/D shall be limited to $L/D = 2.76 - 0.02 \times H$ (see Figure 1).

NOTE H is the hardness in Rockwell C.

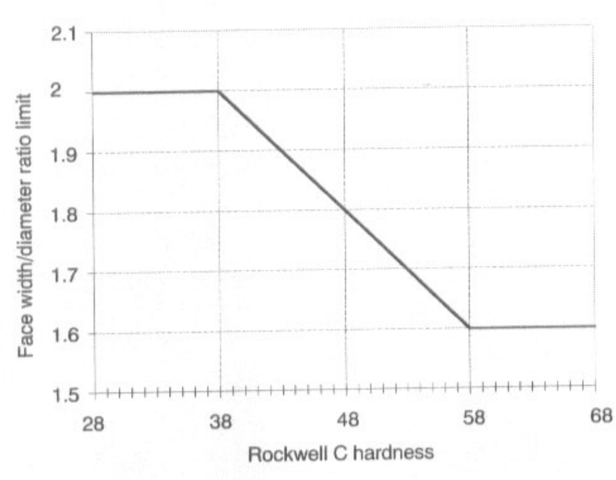


Figure 1—Face Width Limit

6.9.4.4.7 The material used for gearing shall meet the specifications for AGMA 2101 Grade 2 material, as a minimum.

6.9.4.4.8 If a superior grade of material is used, credit for the better material shall not be taken in the gear rating.

6.9.4.4.9 The tooth portion of pinions shall be integral with their shafts.

6.9.4.4.10 The bull gear may be integral with or separate from its shaft.

6.9.4.4.11 Separate shafts shall be assembled into the bull gear with an interference fit suitable for all torque requirements including pulsations. Shaft keys shall not be used to satisfy this requirement.

6.9.4.4.12 Shafts shall be made of one-piece, heat-treated steel that is suitably machined.

6.9.4.4.12.1 Shafts that have a finished diameter larger than 200 mm (8 in.) shall be forged steel.

6.9.4.4.12.2 Shafts that have a finished diameter of 200 mm (8 in.) or less shall be forged steel or, hot rolled bar stock, providing such bar stock meets all quality and heat treatment criteria established for shaft forgings.

6.9.4.4.13 Gearboxes shall not require a break-in period.

6.9.4.4.14 The unplated tooth surface on loaded faces of completed gears shall have a finish, as measured along the pitch line, of 0.8 μm (32 μin.) Ra or better.

6.9.4.4.15 Each gear and each pinion shall be supported between two bearings. Overhung designs are not permitted.

6.9.5 Nameplates and Rotation Arrows

6.9.5.1 Nameplates and rotation arrows shall be in accordance with 6.9.3 of Part 1 and this section.

6.9.5.2 The following data shall be clearly stamped or engraved on the nameplate(s):

— supplier’s name;

— serial number;

— size, type, and model;

— rated capacity;

— rated power;

— gear ratio;

— rated input speed or speed range for variable-speed driver;

— purchaser item number;

— MAWP of each pressure-containing casing;

— maximum and minimum allowable working temperature of each pressure-containing casing;

— hydrostatic test pressure for each pressure-containing casing;

— maximum sealing pressure of each pressure-containing casing.

NOTE Normally, multiple nameplates are provided.

6.9.5.3 Rotation arrows shall be cast-in or attached for the bull gear rotation at a readily visible location.

NOTE See 6.9.3 of Part 1.

7 Accessories

7.1 General

Accessories shall conform to Section 7 of Part 1.

7.2 Lubrication and Sealing Systems

Lubrication and sealing systems shall conform to 7.1 of Part 1.

7.3 Mounting Fixtures

7.3.1 Baseplates and Soleplates

Soleplates and baseplates shall conform to 7.2 of Part 1.

7.3.2 Baseplates

7.3.2.1 Baseplates shall conform to 7.2.2 of Part 1.

7.3.2.2 [●] If specified or approved by the purchaser, the oil reservoir shall be integral with the baseplate.

7.3.2.3 [●] If specified, when machined mounting pads as indicated in 7.3.1 have been specified, the supplier shall also supply the soleplates needed for field installation.

7.4 Controls and Instrumentation

7.4.1 Controls and instrumentation shall be in conformance with 7.3 of Part 1.

7.4.2 Control Systems

7.4.2.1 [●] For a constant-speed centrifugal compressor, the control signal shall actuate either a purchaser-furnished control valve in the compressor inlet piping or the variable inlet guide vanes or variable diffuser vanes furnished by the supplier as an integral part of the compressor, as specified.

7.4.2.2 [●] If variable inlet guide vanes or variable diffuser vanes are specified, the supplier shall also furnish a guide vane positioner compatible with the type of control signal specified by the purchaser.

7.4.2.3 [●] If specified, the guide vane positioner shall include a local manual override.

7.4.2.4 A direct driven vane position indicator shall be provided that will be visible during operation of the machine.

7.4.3 Instrument and Control Panels

Instrument and control panels, when supplied, shall be in accordance with 7.3.3 of Part 1.

7.4.4 Instrumentation

Instrumentation, when supplied, shall be in accordance with 7.3.4 of Part 1.

7.4.5 Alarms and Shutdowns

Alarms and shutdowns, when supplied, shall be in accordance with 7.3.5 of Part 1.

7.4.6 Electrical Systems

Electrical systems, when supplied, shall be in accordance with 7.3.6 of Part 1.

7.4.7 Vibration, Position, and Bearing Temperature

7.4.7.1 The following transducers shall be provided: two radial vibration probes provided adjacent to, or outboard of, each radial bearing. If necessary, the probes can be positioned inboard of the bearings, with the approval of the purchaser.

NOTE On pinion shafts with one impeller, it is common to not measure radial vibration on the opposite end.

7.4.7.2 All shafts with thrust bearings shall have two probes measuring axial position.

7.4.7.3 All shafts with dry gas seals shall have two axial probes measuring axial position and axial vibration.

NOTE This is to monitor excess axial movement and vibration within the dry face seals.

7.4.7.4 One-event-per-revolution probe for each shaft shall be provided.

7.4.7.5 Vibration and axial position transducers shall be supplied, installed, and calibrated in accordance with API 670.

7.4.7.6 [●] If specified, radial shaft vibration and axial position monitors shall be supplied and calibrated in accordance with API 670.

7.4.7.7 Two bearing temperature sensors shall be supplied, installed, and calibrated for each radial and thrust bearing in accordance with API 670.

NOTE The second sensor can be used as a spare.

7.4.7.8 [●] The purchaser shall specify the type of temperature sensors required per API 670.

7.4.7.9 [●] If specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API 670.

7.4.7.10 [●] If specified, an accelerometer shall be supplied, installed at the shaft on the gearbox, and calibrated in accordance with API 670.

NOTE Commercially available accelerometers that have hazardous area certifications have difficulty reaching high gear mesh frequencies.

7.4.7.11 [●] If specified, an accelerometer monitor shall be supplied, installed, and calibrated in accordance with API 670.

7.5 Special Tools

Special tools shall be in accordance with 7.4 of Part 1.

7.6 Couplings and Guards

Couplings and guards shall conform to 7.5 of Part 1.

7.7 Drivers

Drivers shall conform to 7.6 of Part 1.

7.8 Enclosures and Insulation

(Intentionally Left Blank)

7.9 Other Standard Specific Systems

7.9.1 Piping and Appurtenances

7.9.1.1 General

7.9.1.1.1 Piping and appurtenances furnished shall be in accordance with 7.8.1 of Part 1, with additions as follows.

7.9.1.1.2 When a baseplate has been specified, the supplier shall furnish all piping systems, including mounted appurtenances, located within its confines.

7.9.1.1.3 The piping shall terminate with flanged connections at the edge of the baseplate.

7.9.1.1.4 Piping from the edge of the baseplate to other baseplates, equipment, or facilities is furnished by the purchaser.

NOTE The oil reservoir and oil system can be combined in the baseplate. See 7.3.2.2.

7.9.1.2 [●] If specified, a liquid injection manifold including a throttle valve, an armored flow meter, a check valve, a pressure indicator, and a block valve for each injection point shall be supplied.

7.9.2 Process Piping and Accessories

7.9.2.1 Process piping, if furnished, shall be in accordance with API 614.

7.9.2.2 [●] If specified, the purchaser shall furnish piping specifications for supplier furnished process piping.

7.9.2.3 [●] If specified, the supplier shall provide process gas heat exchangers in accordance with purchaser-provided specifications.

NOTE Refer to API 614 for process heat exchanger requirements.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

General requirements for inspection, testing, and preparation for shipment shall be in accordance with 8.1 of Part 1. Also refer to Annex D for the Inspector's Checklist.

8.2 Inspection

8.2.1 General

Requirements for inspection shall be in accordance with 8.2 of Part 1 and the following.

8.2.2 Gear Contact Checks

8.2.2.1 Each set of installed gears shall be checked for contact in the job gearbox at the supplier's shop.

8.2.2.2 A thin coating of color transfer material (such as Prussian blue) shall be applied at three locations, 120° apart, to four or more teeth of the dry degreased gear.

8.2.2.3 Layout dye shall not be used for the assembly contact check.

8.2.2.4 With the gear held firmly, the coated teeth shall be rotated through the mesh with a moderate drag torque applied in a direction that will cause the teeth to contact on the normally loaded faces.

8.2.2.5 The color transfer shall show evidence of contact distributed across each helix, as prescribed by the supplier.

8.2.2.6 Prior to the contact tests, the supplier shall make available to the purchaser a contact drawing or supplier engineering specification that defines the acceptable contact.

8.2.2.7 The results of the contact check shall be preserved by lifting the contrasting colors from a tooth by applying and peeling off a strip of clear, adhesive tape and then applying the tape to a notated sheet of white paper.

NOTE In lieu of contact tape, digital media, such as a digital photograph, can also be acceptable, so long as this is agreed upon between the purchaser and the supplier.

8.2.2.8 The drawing or specification and the results of the contact checks shall be preserved for at least 20 years and shall be available to the purchaser on request.

NOTE Unmodified leads generally show about 80 % contact across the tooth length during full-load testing.

8.3 Testing

8.3.1 General

In addition to the requirements of 8.3 of Part 1, the compressor shall be tested in accordance with 8.3.2 and 8.3.3. Other tests that can be specified are described in 8.3.4.

8.3.2 Mechanical Running Test

8.3.2.1 The requirements of 8.3.2.1.1 through 8.3.2.1.7 shall be met before the mechanical running test is performed.

8.3.2.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

8.3.2.1.2 Compressors covered in Part 3 generally do not use oil-injected seals or seal-oil systems. If these are specified, testing shall be as agreed between the user and the supplier.

NOTE For guidance, see 8.3.5 of Part 1.

8.3.2.1.3 Oil viscosity, pressures, temperatures, and filtration shall be within the range of operating values recommended in the supplier’s operating instructions for the specific unit being tested.

8.3.2.1.4 Overall oil flow rates for each oil supply line shall be measured.

8.3.2.1.5 Oil system components downstream of the filters shall meet the cleanliness requirements of API 614 before any test is started.

8.3.2.1.6 Facilities shall be installed to prevent the entrance of oil into the compressor during the mechanical running test.

8.3.2.1.7 These facilities shall be in operation throughout the test.

8.3.2.2 The mechanical running test of the equipment shall be conducted as specified in 8.3.2.2.1 through 8.3.2.2.4.

NOTE Testing with the contract coupling(s) is preferred.

8.3.2.2.1 The equipment shall be accelerated to the maximum continuous speed and run until bearings, lube-oil temperatures, and shaft vibrations have stabilized [1 °C (2 °F) over 10 minutes].

NOTE 1 Operating equipment at or near critical speeds is normally avoided.

NOTE 2 Refer to Figure 2 for a graphical illustration of the complete mechanical running test.

8.3.2.2.2 For variable-speed machines, the speed shall be increased to trip speed and the equipment shall be run for a minimum of 15 minutes.

8.3.2.2.3 The speed shall be reduced to the N_{mc}, and the equipment shall be run for 4 hours continuous operation.

8.3.2.2.4 The unit shall be tripped and allowed to coast to a stop.

8.3.2.3 During the mechanical running test, the requirements of 8.3.2.3.1 through 8.3.2.3.6 shall be met.

8.3.2.3.1 During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall meet the agreed requirements.

8.3.2.3.1.1 The equipment measured unfiltered radial vibration shall not exceed the limits of 6.8.9.1 of Part 1.

8.3.2.3.1.2 The equipment measured unfiltered radial vibration shall be recorded at the operating speed.

8.3.2.3.1.3 Any other test acceptance criteria shall be agreed and stated in the test agenda.

8.3.2.3.2 Axial displacement (motion with a frequency less than 0.5 Hz) limits shall be determined by the compressor supplier and the gas seal supplier and be communicated to the purchaser.

8.3.2.3.3 While the equipment is operating at N_{mc} or other speeds, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous.

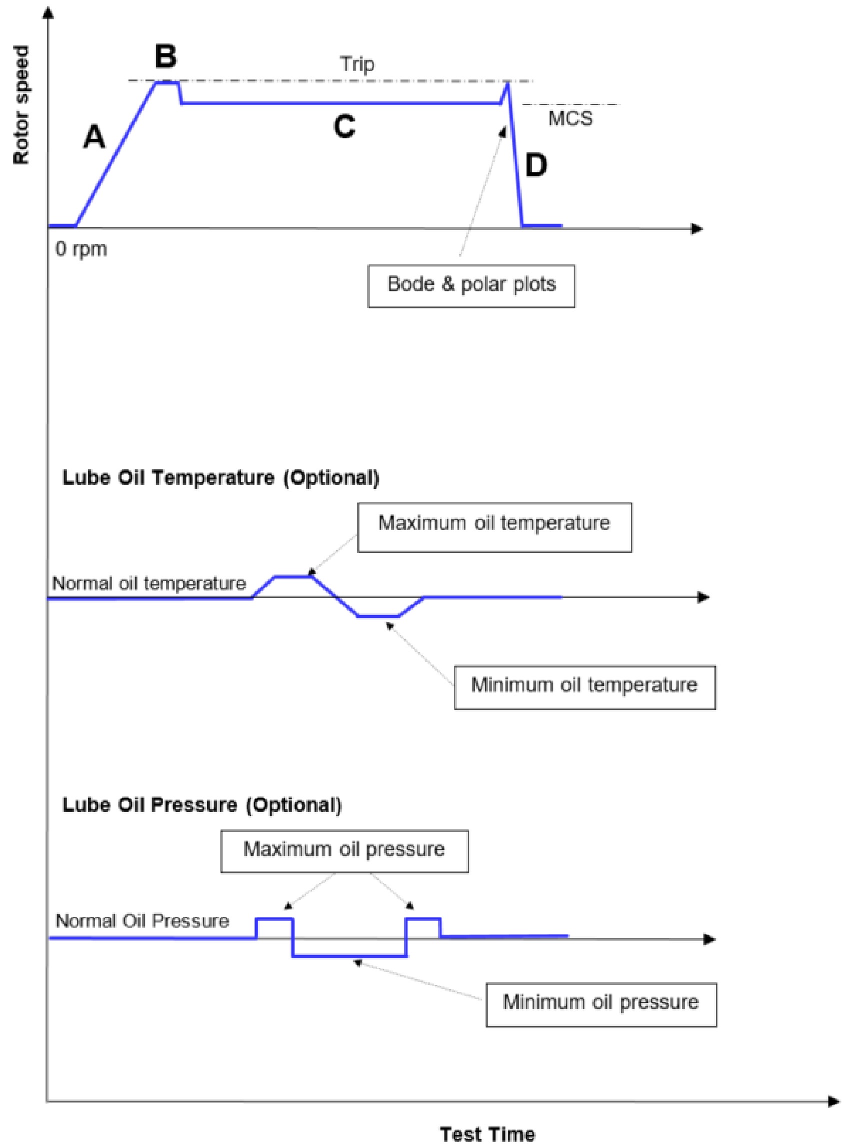
8.3.2.3.3.1 These data shall cover a frequency range from 0.25 to 8 times the N_{mc}.

8.3.2.3.3.2 If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in 6.8.9.1 of Part 1, the purchaser and the supplier shall agree on requirements for any additional testing and on the equipment acceptability.

8.3.2.3.4 The mechanical running test shall verify that lateral critical speeds below running speed conform to the requirements of 6.8.2 of Part 1.

8.3.2.3.5 [●] If specified, all real-time vibration data as agreed by the purchaser and the supplier shall be recorded and a copy provided to the purchaser.

8.3.2.3.6 [●] If specified, the user may bring in vibration equipment to record baseline readings.



Key

A ramp-up phase

— speed increased to MCS

B trip speed operation

— 15 minutes

C maximum continuous speed 4-hour test

— oil supply variations performed

— operating conditions recorded

D shutdown/ramp down

— momentary increase to trip speed

— transient operation recorded

Figure 2—Mechanical Running Test

8.3.2.4 Following the mechanical running test, the requirements of 8.3.5.10 of Part 1 shall be met, as well as the requirements of 8.3.2.4.1 and 8.3.2.4.3 below.

8.3.2.4.1 The tooth mesh shall be visually inspected for proper contact and for surface damage resulting from the test, and as specified in 8.2.2.

8.3.2.4.2 In cases where the compressor is not fully loaded during shop testing, the acceptable criteria for proper contact shall be agreed prior to the test.

8.3.2.4.3 Spare rotor sets ordered to permit concurrent manufacture shall also be given a mechanical running test in accordance with the requirements of this standard.

8.3.2.4.4 Complete spare set shall be run as a unit.

8.3.3 Assembled Compressor Gas Leakage Test

8.3.3.1 After the mechanical running test is completed, each completely assembled compressor casing intended for toxic, hazardous, or flammable service shall be tested as required in 8.3.3.2 and/or, if specified, 8.3.3.3.

NOTE These tests are intended to verify the integrity of the casing joint. Some shaft seal designs are not gas tight. Therefore, leakage from these seals during this test is acceptable.

8.3.3.2 The assembled compressor (including end seals) shall be pressurized, with an inert gas, to the maximum sealing pressure or an agreed maximum seal design pressure and held at no less than this pressure for a minimum of 30 minutes and subjected to a soap bubble test, or alternate method, to check for gas leaks.

8.3.3.2.1 The test shall be considered satisfactory when no casing or casing joint leaks is observed.

8.3.3.2.2 Test gas mole weight shall be equal to or less than the contract gas mole weight.

8.3.3.3 [●] If specified, the assembled compressor (with or without end seals installed) shall be pressurized with an inert gas to the maximum specified discharge pressure, held at this pressure for a minimum of 30 minutes, and subjected to a soap bubble test, or alternate method, to check for gas leaks.

NOTE The requirements of 8.3.3.2 and 8.3.3.3 can necessitate two separate tests.

8.3.4 Optional Tests

8.3.4.1 General

8.3.4.1.1 [●] The purchaser will specify whether any of the following shop tests shall be performed.

8.3.4.1.2 The purchaser and the supplier shall agree upon test details prior to the test.

8.3.4.2 Performance Test

8.3.4.2.1 The compressor shall be performance tested in accordance with ASME PTC 10 or ISO 5389, as specified.

8.3.4.2.1.1 A minimum of five points, including surge and overload, shall be taken at normal operating point with regard to speed and vane setting.

8.3.4.2.1.2 [●] For variable-speed or variable-vane machines, additional points may be specified by the purchaser.

NOTE Refer to the applicable test code for general instructions. ASME PTC 10 will not apply to some low-pressure ratio compressors. Refer to the scope 1.2.2 of PTC 10 for the selection of the appropriate test code to be used.

8.3.4.2.2 For variable-speed or variable-vane machines, head shall have zero negative tolerance at the certified operating point capacity (or other point as specified).

8.3.4.2.2.1 The power at this point shall not exceed 104 % of the supplier predicted shaft power value. This tolerance shall be inclusive of all test tolerances.

NOTE Both of the performance test codes referred to have provision for calculating inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore, are not to be further additive.

8.3.4.2.2.2 Surge shall comply with provisions of 6.1.1.

8.3.4.2.3 For constant-speed compressors, the capacity shall be as specified in 8.3.4.2.2.

8.3.4.2.3.1 The head shall be within the range of 100 % to 105 % of the normal head.

8.3.4.2.3.2 The power, based on measured head at normal capacity, shall not exceed 107 % of the value at the specified normal operating point.

8.3.4.2.3.3 If the power required at this point exceeds 107 %, excess head may be removed by trimming impellers at the purchaser's option.

8.3.4.2.4 The performance test shall be conducted using only one contract rotor set, unless additional performance testing is specified.

8.3.4.2.5 Compressors with intermediate specified process pressures shall have individual sectional head (pressure) tolerances as agreed.

8.3.4.3 Complete Unit Test

8.3.4.3.1 Such components as compressors, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test.

8.3.4.3.2 A separate auxiliary test may be performed with the purchaser's approval.

8.3.4.3.3 The complete unit test may be performed in place of or in addition to separate tests of individual components specified by the purchaser.

8.3.4.3.4 [●] If specified, torsional vibration measurements shall be made to verify the vendor's analysis.

8.4 Preparation for Shipment

8.4.1 Preparation for shipment shall be in accordance with 8.4 of Part 1.

8.4.2 [●] If specified, the fit-up and assembly of machine-mounted piping, heat exchangers, etc. shall be completed in the vendor's shop prior to shipment.

9 Supplier's Data

9.1 General

9.1.1 Vendor's data shall be in accordance with Section 9 of Part 1.

9.1.2 [●] If specified, the information to be furnished by the vendor is specified in Annex B and Part 1 Annex I and supplied per 9.1.2.1 and 9.1.2.2.

9.1.2.1 The supplier shall complete and forward the vendor drawing and data requirements (VDDR) Form (see Annex B) to the address or addresses noted on the inquiry or order.

9.1.2.2 This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

9.1.2 On the datasheets and in drawings and tables, the shaft rotational direction shall be designated by the abbreviations CW (clockwise) or CCW (counterclockwise) (see 6.9.5.3).

9.1.3 Suppliers shall provide bearing temperature alarm and shutdown limits.

9.2 Proposals

Proposals shall be in accordance with I.2 of Part 1.

9.3 Contract Data

Contract data shall be in accordance with I.3 of Part 1.

Annex A
(informative)

Typical Datasheets

A representation of the datasheets is enclosed in this annex; however, MS Excel format datasheets have been developed and are available, for purchase from API publications distributors, with this standard. The MS Excel electronic datasheets may have additional functionality over printed hard copies.

	REVISION	0	1	2	3	4
	DATE					
	BY					
INTEGRALLY GEARED COMPRESSOR DATASHEET (API 617-9th, Part 3) SI UNITS (bar)	REV/APPR					
	JOB NO.		ITEM NO.			
	PAGE	1	OF	12	REQ'N NO.	

1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

2 FOR ______ UNIT ______

3 SITE ______ SERIAL NO. ______

4 SERVICE ______ NO. REQUIRED ______

5 MANUFACTURER ______ DRIVER TYPE ______

6 MODEL ______ DRIVER ITEM NO. ______

7 APPLICABLE STANDARD: ○ US ○ ISO

8 INFORMATION TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

9 **OPERATING CONDITIONS**

		NORMAL	OTHER CONDITIONS				
11	(ALL DATA ON PER UNIT BASIS)		RATED	B	C	D	E
12		(NOTE 1)					
13	○ GAS HANDLED (ALSO SEE PAGE ___)						
14	△ GAS PROPERTIES						
15	○ STANDARD VOLUME FLOW N(m³/h) (1.013 barA & 0°C DRY)						
16	○ WEIGHT FLOW (lb/min) ○ WET ○ DRY						
17	**INLET CONDITIONS**						
18	○ PRESSURE (barA)						
19	○ TEMPERATURE (°C)						
20	○ RELATIVE HUMIDITY %						
21	○ MOLECULAR WEIGHT						
22	□ Cp/Cv (K_1) OR (K_{AVG})						
23	□ COMPRESSIBILITY (Z_1) OR (Z_{AVG})						
24	□ INLET VOLUME (m³/h) ○ WET ○ DRY						
25	**DISCHARGE CONDITIONS**						
26	○ PRESSURE (barA)						
27	□ TEMPERATURE (°C) **(ESTIMATED)**						
28	□ Cp/Cv (K_2) OR (K_{AVG})						
29	□ COMPRESSIBILITY (Z_2) OR (Z_{AVG})						
30	□ GHP REQUIRED (kW)						
31	□ TRAIN (BkW) REQUIRED						
32	□ (BkW) REQUIRED AT DRIVER INCL. EXT. LOSSES (GEAR, ETC.)						
33	□ SPEED OF DRIVER (rpm)						
34	□ TURNDOWN (%)						
35	□ POLYTROPIC HEAD (N-m/kg)						
36	□ POLYTROPIC EFFICIENCY (%)						
37	○ CERTIFIED POINT						
38	□ PERFORMANCE CURVE NUMBER						

39 **PROCESS CONTROL**

40 ○ METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ VARIABLE DIFFUSER

41 FROM ______ (barA) GUIDE VANES FROM ______ % BLOWOFF OR GUIDE VANES

42 TO ______ (barA) TO ______ % RECIRCULATION

43 SIGNAL ○ SOURCE ______

44 TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______

45 RANGE ______ (mA) ______ (barG) ______

46 **REMARKS:** NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY GAS PROPERTIES, OTHERWISE DATA SHALL BE SUPPLIED BY USER

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INTEGRALLY GEARED COMPRESSOR
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SI UNITS (bar)

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OPERATING CONDITIONS (Continued)

GAS ANALYSIS:			OTHER CONDITIONS					
◯ MOL %		**NORMAL**	**RATED**	**B**	**C**	**D**	**E**	**REMARKS:**
	MW							
AIR	28.966							
OXYGEN	32.000							
NITROGEN	28.016							
WATER VAPOR	18.016							
CARBON MONOXIDE	28.010							
CARBON DIOXIDE	44.010							
HYDROGEN SULFIDE	34.076							
HYDROGEN	2.016							
METHANE	16.042							
ETHYLENE	28.052							
ETHANE	30.068							
PROPYLENE	42.078							
PROPANE	44.094							
I-BUTANE	58.120							
n-BUTANE	58.120							
I-PENTANE	72.146							
n-PENTANE	72.146							
CORROSIVE AGENTS								
TOTAL								
AVG. MOL. WT.								

LOCATION:
◯ INDOOR ◯ OUTDOOR ◯ GRADE
◯ HEATED ◯ UNDER ROOF ◯ MEZZANINE
◯ UNHEATED ◯ PARTIAL SIDES ◯ ____

SITE DATA
◯ ELEVATION ____ (m) BAROMETER ____ (barA)
◯ RANGE OF AMBIENT TEMPS:

		DRY BULB	WET BULB
NORMAL	(°C)	____	____
MAXIMUM	(°C)	____	____
MINIMUM	(°C)	____	____
____	(°C)	____	____

UNUSUAL CONDITIONS: ◯ DUST ◯ FUMES
____ ____ ____
◯ OTHER ____
____
◯ COPPER AND COPPER ALLOYS PROHIBITED

COATING:
◯ ROTATING COMPONENTS ____
◯ STATIONARY COMPONENTS ____

REMARKS: ____

NOISE SPECIFICATIONS:
◯ APPLICABLE TO MACHINE:
SEE SPECIFICATION ____
◯ APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION ____
ACOUSTIC HOUSING: ◯ YES ◯ NO

APPLICABLE SPECIFICATIONS:
API 617-9th Part 3
◯ VENDOR HAVING UNIT RESPONSIBILITY
____
◯ GOVERNING SPECIFICATION (IF DIFFERENT)
____
◯ ELEC. AREA CLASS. ◯ NEC ◯ IEC
EQUIPMENT
CLASS ____ GROUP ____ DIV. ____
ZONE ____ GROUP ____ TEMP CLASS ____
CONTROL PANNELS
CLASS ____ GROUP ____ DIV. ____
ZONE ____ GROUP ____ TEMP CLASS ____
◯ INSTRUMENT AND CONTROLS
STANDARD ◯ NEMA ◯ IEC

	INDOOR	OUTDOOR
CONTROL ENCLOSURE	____	____
TERMINAL BOX	____	____

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1	**CONSTRUCTION FEATURES (1 COLUMN PER STAGE, USE ADDITIONAL SHEETS IF NEEDED)**						
2	**Rotor**	Rotor 1					
3	**Stage**	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
4	☐ **CASING:**						
5	MODEL						
6	CASING SPLIT						
7	MATERIAL						
8	THICKNESS (mm)						
9	CORROSION ALLOWANCE (mm)						
10	MAX. ALLOWABLE PRESS (barG)						
11	TEST PRESS (barG)						
12	MAX. ALLOWABLE TEMP. (°C)						
13	MAX. OPERATING TEMP. (°C)						
14	MIN. OPERATING TEMP. (°C)						
15	MAX CASING CAPACITY (m^3/h)						
16	☐ **INLET CONNECTIONS**						
17	TYPE						
18	ORIENTATION						
19	FLANGED OR STUDDED?						
20	MATING FLG & GASKET BY VENDOR?						
21	GAS VELOCITY (m/s)						
22	☐ **DISCHARGE CONNECTIONS**						
23	TYPE						
24	ORIENTATION						
25	FLANGED OR STUDDED?						
26	MATING FLG & GASKET BY VENDOR?						
27	GAS VELOCITY (m/s)						
28	○ **INTERMEDIATE MAIN PROCESS CONNECTIONS**						
29	DISCH. PRESSURE (barG)						
30	INLET PRESSURE (barG)						
31	☐ **ADJUSTABLE INLET GUIDE VANES**						
32	MATERIAL ____						
33	NO. INLET GUIDE VANES						
34	○ BUFFERED ACTUATOR SEAL (Y or N)						
35	☐ **IMPELLER:**						
36	DIAMETER						
37	NUMBER OF VANES						
38	TYPE (OPEN, ENCLOSED, ETC.)						
39	TYPE FABRICATION						
40	MATERIAL						
41	MIN. YIELD STRENGTH (MPa)						
42	HARDNESS: (Rc) (BRINNEL)						
43	SMALLEST TIP INTERNAL WIDTH (mm)						
44	MAX. MACH. NO. @ IMPELLER EYE						
45	MAX. IMPELLER HEAD @ 100% SPEED (m)						
46	MAX. IMPELLER TIP SPEED (m/s)						
47	☐ **DIFFUSER GUIDE VANES**						
48	ADJUSTABLE?						
49	MATERIAL						
50	NO. GUIDE VANES						
51	**REMARKS:**						
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1 **CONSTRUCTION FEATURES, continued (1 COLUMN PER STAGE, USE ADDITIONAL SHEETS IF NEEDED)**

		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
2	☐ **SHAFT SLEEVES:**						
3	MATERIAL						
4	AT SHAFT SEALS?						
5	OTHER LOCATIONS?						
6	**SHAFT SEALS:**						
7	○ SEAL TYPE						
8	○ SETTLE OUT PRESSURE (barG)						
9	○ MINIMUM SEALING PRESSURE (barG)						
10	○ TYPE BUFFER GAS, PRIMARY						
11	☐ PRESSURE (barG)						
12	☐ FLOW RATE (kg/h)						
13	☐ FILTRATION						
14	○ TYPE BUFFER GAS, SECONDARY						
15	☐ PRESSURE (barG)						
16	☐ FLOW RATE (kg/h)						
17	☐ FILTRATION						
18	☐ FLOW RATE TO PROCESS						

19 ○ BUFFER GAS SYSTEM REQUIRED
20 ○ MANIFOLD
21 ○ METHOD OF CONTROL ____
22 ○ BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR
23 ○ PRESSURIZING GAS FOR SUBATMOSPHERIC SEALS ○ EDUCTOR ○ INJECTION
24 ☐ SEAL MANUFACTURER ____ ○ SYSTEM RELIEF VALVE SET PT. ____

25 **BEARING TEMPERATURE DETECTORS**
26 ○ SEE ATTACHED API-670 DATASHEET
27 ○ THERMOCOUPLES TYPE ____
28 ○ RESISTANCE TEMP DETECTORS
29 ○ RESISTANCE MATERIAL ____ ○ ____ (ohm)
30 ☐ ALARM TEMPERATURE (°C) ____
31 ☐ SHUTDOWN TEMPERATURE (°C) ____
32 ○ PROVISION FOR LOCAL DISCONNECT
33 ○ LOCATION-JOURNAL BEARING
34 NO. ____ EA PAD ____ EVERY OTHER PAD ____ PER BEARING
35 OTHER ____
36 ○ LOCATION-THRUST BEARING
37 NO. ____ EA PAD ____ EVERY OTHER PAD ____ PER BEARING
38 OTHER ____
39 NO. (INACT) ____ EA PAD ____ EVERY OTHER PAD ____ PER BEARING
40 OTHER ____
41 ○ LOCAL DISCONNECTION
42 ○ MONITOR SUPPLIED BY ____
43 ○ LOCATION ____ ENCLOSURE ____
44 ○ MFR. ____ ☐ MODEL ____
45 ☐ SCALE RANGE ____ ALARM ☐ SET @ ____ (°C)
46 ○ SHUTDOWN: ☐ SET @ ____ (°C) ○ TIME DELAY ____ (sec)
47 **KEY PHASOR REQUIRED**
48 ○ COMPRESSOR ○ GEAR H.S. ○ GEAR L.S.

25 **VIBRATION DETECTORS:** ○ SEE ATTACHED API-670 DATASHEET
26 ○ TYPE ____ ☐ MODEL ____
27 ○ MFR ____
28 ○ NO. AT EA SHAFT BEARING ____ TOTAL NO. ____
29 ○ OSCILLATOR-DETECTORS SUPPLIED BY ____
30 ○ MFR ____ ☐ MODEL ____
31 ○ MONITOR SUPPLIED BY ____
32 ○ LOCATION ____ ENCLOSURE ____
33 ○ MFR. ____ ☐ MODEL ____
34 ☐ SCALE RANGE ____ ALARM ☐ SET @ ____ (μm)
35 ○ SHUTDOWN: ☐ SET @ ____ (μm) ○ TIME DELAY ____ (sec)
36 ○ CASING VIBRATION TRANSDUCERS
37 ○ CASING VIBRATION MONITORS
38 **AXIAL POSITION/VIBRATION DETECTOR:**
39 ○ SEE ATTACH. API-670 DATASHEET
40 ○ TYPE ____ ☐ MODEL ____
41 ○ MFR ____ ○ NO. REQUIRED ____
42 ○ OSCILLATOR-DEMODULATOR SUPPLIED BY ____
43 ○ MFR ____ ☐ MODEL ____
44 ○ MONITOR SUPPLIED BY ____
45 ○ LOCATION ____ ENCLOSURE ____
46 ○ MFR. ____ ☐ MODEL ____
47 ☐ SCALE RANGE ____ ALARM ☐ SET @ ____ (μm)
48 ○ SHUTDOWN: ☐ SET @ ____ (μm) ○ TIME DELAY ____ (sec)

49 **REMARKS:** ____
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CONSTRUCTION FEATURES, ROTORS (1 COLUMN PER ROTOR, USE ADDITIONAL SHEETS IF NEEDED)

☐ **DRIVER SPEEDS:**

MAX. CONT. ____

TRIP SPEED ____

PITCH LINE VELOCITY (m/s) ____

NORMAL DIAMETRAL PITCH ____

HELIX ANGLE ____ PRESSURE ANGLE ____

☐ ROTOR NUMBER	BULL GEAR	ROTOR 1	ROTOR 2	ROTOR 3	ROTOR 4
SPEED (rpm)					
SERVICE POWER (kW)					
SERVICE FACTOR					
NUMBER OF TEETH					
FACE WIDTH (mm)					
AGMA GEOMETRY FACTOR "J"					
AGMA GEOMETRY FACTOR "I"					
MINIMUM HARDNESS (Rc)					
ROTOR WEIGHT (INC WHEELS) (kg)					
BACKLASH (mm)					
GEARBOX FULL LOAD POWER LOSS					
☐ **LATERAL CRITICAL SPEEDS (DAMPED)**					
FIRST CRITICAL					
SECOND CRITICAL					
THIRD CRITICAL					
FOURTH CRITICAL					

○ LATERAL ANALYSIS ADDITIONAL REQUIREMENTS

○ TRAIN LATERAL ANALYSIS REQUIRED

○ TORSIONAL ANALYSIS REQUIRED

☐ **TORSIONAL CRITICAL SPEEDS:**	
FIRST CRITICAL	
SECOND CRITICAL	
THIRD CRITICAL	
FOURTH CRITICAL	

○ LIST OF TRAIN UNDESIRABLE SPEEDS

○ STABILITY ANALYSIS

☐ **VIBRATION:**					
ALLOWABLE RADIAL TEST LEVEL (P-P) (µm)					
ALLOWABLE AXIAL TEST LEVEL (P-P) (µm)					
AXIAL DISPLACEMENT LIMIT (µm)					
☐ **BALANCE PISTON:**					
MATERIAL					
FIXATION METHOD					
NORMAL CLEARANCE (mm)					
AREA (mm²)					
FLOW, NORMAL CLEARANCE (kg/h)					
FLOW, 2x NORMAL CLEAR (kg/h)					
○ PRESS. CONN. BAL LINE					

REMARKS:

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CONSTRUCTION FEATURES, ROTOR BEARINGS (1 COLUMN PER ROTOR, USE ADDITIONAL SHEETS IF NEEDED)

RADIAL BEARINGS, DRIVE END	BULL GEAR	ROTOR 1	ROTOR 2	ROTOR 3	ROTOR 4
☐ TYPE					
☐ MANUFACTURER					
☐ LENGTH (mm)					
☐ SHAFT DIAMETER (mm)					
☐ UNIT LOAD (ACT/ALLOW)					
☐ BASE MATERIAL					
☐ NUMBER OF PADS					
☐ LOAD: BETWEEN/ON PAD					
☐ PIVOT: CENTER/OFFSET, %					
☐ RADIAL BEARING SPAN					
☐					
RADIAL BRG, OPPOSITE DRIVE END					
☐ TYPE					
☐ MANUFACTURER					
☐ LENGTH (mm)					
☐ SHAFT DIAMETER (mm)					
☐ UNIT LOAD (ACT/ALLOW)					
☐ BASE MATERIAL					
☐ NUMBER OF PADS					
☐ LOAD: BETWEEN/ON PAD					
☐ PIVOT: CENTER/OFFSET, %					
☐					
THRUST BEARINGS, ACTIVE					
☐ TYPE					
☐ MANUFACTURER					
☐ UNIT LOADING (max) (MPa)					
☐ UNIT LOAD (ULT.) (MPa)					
☐ AREA (mm²)					
☐ NUMBER OF PADS					
☐ PIVOT: CENTER / OFFSET, %					
☐ PAD BASE MATERIAL					
○ COPPER BACKED PERMITTED?					
☐ COLLAR MATERIAL					
☐ INTEGRAL OR REPLACEABLE COLLAR?					
☐ SIZING CRITERIA					
☐ FLOODED OR DIRECTED LUBRICATION?					
THRUST BEARINGS, INACTIVE					
☐ TYPE					
☐ MANUFACTURER					
☐ UNIT LOADING (max) (MPa)					
☐ UNIT LOAD (ULT.) (MPa)					
☐ AREA (mm²)					
☐ NUMBER OF PADS					
☐ PIVOT: CENTER / OFFSET, %					
☐ PAD BASE MATERIAL					
○ COPPER BACKED PERMITTED?					
☐ COLLAR MATERIAL					
☐ INTEGRAL OR REPLACEABLE COLLAR?					
☐ SIZING CRITERIA					
☐ FLOODED OR DIRECTED LUBRICATION?					

REMARKS:

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INTEGRALLY GEARED COMPRESSOR
DATASHEET (API 617-9th, Part 3)
SI UNITS (bar)

JOB NO. ____ ITEM NO. ____
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1 ☐ **OTHER CONNECTIONS**

2 **SERVICE:**

SERVICE	NO.	SIZE	TYPE	SERVICE	NO.	SIZE	TYPE
3 ☐ LUBE-OIL INLET				☐ PRESSURE			
4 ☐ LUBE OIL OUTLET				☐ TEMPERATURE			
5 ☐ SEAL-OIL INLET				☐ SOLVENT INJECTION			
6 ☐ SEAL-OIL OUTLET				☐ PURGE FOR:			
7 ☐ SEAL GAS INLET				☐ BRG. HOUSING			
8 ☐ SEAL GAS OUTLET				☐ BTWN BRG & SEAL			
9 ☐ CASING DRAINS				☐ BTWN SEAL & GAS			
10 ☐ STAGE DRAINS				____			

11 ○ INDIVIDUAL STAGE DRAINS REQUIRED
12 ○ VALVED & BLINDED
13 ○ VALVED & BLINDED & MANIFOLD

14 **LUBRICATION AND SEALING SYSTEMS**

15 ○ SEE ATTACHED API 614 DATASHEET
16 ○ SEPARATE ○ COMBINED
17 ○ INTEGRAL OIL RESERVOIR
18 △ OIL TYPE

19 **ACCESSORIES**

20 **COUPLING AND GUARDS**
21 NOTE: SEE ROTATING ELEMENTS - SHAFT ENDS
22 ○ SEE ATTACHED API 671 DATASHEET ○ KEYLESS HYDRAULIC ○ KEYED ○ FLANGED ○ OTHER ____
23 COUPLING FURNISHED BY ____ MOUNTED BY ____
24 MANUFACTURER ____ TYPE ____ MODEL ____
25 COUPLING GUARD FURNISHED BY: ____
26 TYPE: ○ FULLY ENCLOSED ○ SEMI-OPEN ○ OTHER ____

27 **COUPLING DETAILS**
28 ☐ MAX O.D. ____ (mm) ○ PLUG AND RING GAUGES ○ LAPPING TOOL
29 ☐ HUB WEIGHT ____ (kg) COOLING REQUIREMENTS
30 ☐ SPACER LENGTH ____ (mm) ☐ FLOW RATE ____ (L/min)
31 ☐ SPACER WEIGHT ____ (kg)

32 **MOUNTING PLATES**

33 ○ BASEPLATES FURNISHED BY ____ ○ SOLEPLATES FURNISHED BY ____
34 ○ COMPRESSOR ONLY ○ DRIVER ○ GEAR ☐ THICKNESS ____ (mm)
35 ○ OTHER ____ ○ ____
36 ○ NONSKID DECKING ○ SLOPED DECK
37 △ LEVELING PADS OR TARGETS ☐ SHIM THICKNESS ____ (mm)
38 △ COLUMN MOUNTING
39 ○ SUB-SOLE PLATES REQUIRED
40 ☐ STAINLESS STEEL SHIM THICKNESS ____ (mm) ○ COUNTER BORE ANCHOR BOLT HOLES
41 ○ MACHINED MOUNTING PADS REQUIRED

42 ANTI-SURGE SYSTEM FURNISHED BY ○ PURCHASER ☐ VENDOR
43 ○ ☐ ANTI-SURGE VALVE ○ SIZING ONLY
44 PRESSURE UPSTREAM: ____ (barG) DOWNSTREAM: ____ (barG)
45 ☐ ∆ P VALVE ____ (bar) STROKE TIME OPEN - CLOSE ____ (sec)
47 ○ ☐ RECIRCULATION VALVE ○ SIZING ONLY **REMARKS:** ____
48 ○ ☐ BLOWOFF VALVE ○ SIZING ONLY
49 ○ ☐ CONTROL SYSTEM
50 ○ ☐ PIPING
51 ○ ☐ FLOW ELEMENT
52 ○ ☐ ____ ○ ☐ ____
53 ○ ☐ ____ ○ ☐ ____
54 ○ ☐ ____ ○ ☐ ____
55 ○ ☐ ____ ○ ☐ ____
56 ○ ☐ ____ ○ ☐ ____

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INTEGRALLY GEARED COMPRESSOR
DATASHEET (API 617-9th, Part 3)
SI UNITS (bar)

JOB NO. ____ ITEM NO. ____
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UTILITIES

○ **UTILITY CONDITIONS:**

STEAM:	DRIVERS	
INLET MIN	____ (barG)	____ (°C)
NORM	____ (barG)	____ (°C)
MAX	____ (barG)	____ (°C)
EXHAUST. MIN	____ (barG)	____ (°C)
NORM	____ (barG)	____ (°C)
MAX	____ (barG)	____ (°C)

ELECTRICITY:

	DRIVERS	CONTROL	SHUTDOWN
VOLTAGE			
HERTZ			
PHASE			

○ REDUCED VOLTAGE START
△ NUMBER OF STARTS ____
○ **INSTRUMENT AIR:**
MAX PRESS ____ (psig) MIN PRESS ____ (barG)
☐ **ROTATION, VIEWED OPP. DRIVE END** ○ **CW** ○ **CCW**

MANUALS
○ DRAFT MANUAL FOR REVIEW
○

MISCELLANEOUS: **TECHNICAL DATA MANUAL**
☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
BEFORE SUCTION ____
○ COMPRESSOR TO BE SUITABLE FOR FIELD RUN-IN ON AIR
○ PROVISION FOR LIQUID INJECTION ____
○ INJECTION MANIFOLD
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEM
○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING / FOUNDATION
○ SHOP FIT-UP OF VENDOR PROCESS PIPING
○ WELDING HARDNESS TESTING
____
○ DESIGN AUDIT
○ BALANCE PISTON ΔP
○ PROVIDE TAIL END SCHEDULES
○ BORESCOPIC INSPECTION PORTS

SHOP INSPECTION AND TESTS:

○ (SEE INSPECTOR'S CHECKLIST)	REQ'D	WIT/OBV
HYDROSTATIC	●	
IMPELLER OVERSPEED	●	
MECHANICAL RUN	●	
○ CONTRACT COUPLING ○ IDLING ADAPTOR(S)		
○ CONTRACT PROBES ○ SHOP PROBES		
○ PURCHASER VIB. EQUIPMENT		
VARY LUBE OIL PRESSURES AND TEMPERATURES	○	
REASSEMBLY CHECK BALANCE	○	
POLAR FORM VIB DATA	○	
RECORD VIB DATA	○	
SHAFT END SEAL INSP	○	
GAS LEAK TEST AT DISCH PRESS	○	
○ POST TEST INTERNAL INSP		
○ BEFORE GAS LEAKAGE TEST		
○ AFTER GAS LEAKAGE TEST	○	
PERFORMANCE TEST	○	
COMPLETE UNIT TEST	○	
TANDEM TEST	○	
GEAR TEST	○	
HELIUM LEAK TEST	○	
SOUND LEVEL TEST	○	
AUX. EQUIPMENT TEST ____	○	
FULL LOAD / SPEED / PRESS TEST	○	
HYDRAULIC COUPLING FIT INSP	○	
SPARE PARTS TEST ____	○	
INSPECTOR'S CHECKLIST COMPLIANCE	○	
GAS SEAL TEST VENDOR SHOP	○	

VENDOR'S REPRESENTATIVE SHALL
○ OBSERVE FLANGE PARTING
○ CHECK ALIGNMENT AT TEMPERATURE
○ BE PRESENT AT INITIAL ALIGNMENT

☐ **WEIGHTS:** (kg)
COMPR. ____ GEAR ____ DRIVER ____ BASE ____
ROTORS: COMPR. ____ DRIVER ____ GEAR ____
COMPRESSOR UPPER CASE ____
MAX. FOR MAINTENANCE (IDENTIFY) ____
TOTAL SHIPPING WEIGHT ____

☐ **SPACE REQUIREMENTS:** (mm)
COMPLETE UNIT: L ____ W ____ H ____

SPECIAL TOOL PACKAGING:
○ METAL STORAGE CONTAINER
○ OTHER: ____

PAINTING:
○ MANUFACTURER'S STD.
○ OTHER ____
NAMEPLATE ○ US CUSTOMARY ○ METRIC
SHIPMENT:
○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQ'D.
○ OUTDOOR STORAGE MORE THAN 6 MONTHS ____ MO
SPARE ROTOR ASSEMBLY PACKAGE
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ METAL STORAGE CONTAINER
○ N2 PURGE ○ OTHER: ____

MATERIALS INSPECTION REQUIREMENTS

○ RADIOGRAPHY REQUIRED FOR ____
○ ULTRASONIC REQUIRED FOR ____
○ MAGNETIC PARTICLE REQUIRED FOR ____
○ LIQUID PENETRANT REQUIRED FOR ____

○ LOW TEMPERATURE
MIN.DESIGN METAL TEMPERATURE ____ (°C)
AT CONCURRANT PRESSURE ____ (barG)
○ OTHER TRAIN COMPONENTS
○ Q.C. OF INACCESSIBLE WELDS

REMARKS: ____

INTEGRALLY GEARED COMPRESSOR DATASHEET (API 617-9th, Part 3) SI UNITS (bar)	REVISION	0	1	2	3	4
	DATE					
	JOB NO.		ITEM NO.			
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1 INTER COOLER(S) - BETWEEN 1st and 2nd STAGE

2 SERVICE OF UNIT: ______ ITEM NO. ______

3 SIZE: ______ TYPE: ______ ☐ HORIZ ☐ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES

4 SURF/UNIT: (GROSS/EFF) ______ (m²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______

5 PERFORMANCE OF ONE UNIT

6

No.		SHELL SIDE		TUBE SIDE	
7		SHELL SIDE		TUBE SIDE	
8	◯ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (kg/h)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°C)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUID (mPa-s)				
15	☐ SPECIFIC HEAT (kJ/kg °C)				
16	☐ THERMAL CONDUCTIVITY (kJ/m h °C)				
17	☐ LATENT HEAT (kJ/kg °C)				
18	☐ INLET PRESSURE (barG)				
19	◯ VELOCITY (m/s)				
20	◯ PRESSURE DROP--ALLOW/CALC (bar)				
21	◯ FOULING RESISTANCE--MINIMUM (hr m² °C/kJ)				

22 ☐ HEAT EXCHANGED ______ (kJ/hr) ΔT_{MEAN} CORRECTED ______ (°C)

23 ☐ TRANSFER RATE, (kJ/hr m² °C) SERVICE ______ CLEAN ______

24 ☐ CONSTRUCTION OF ONE SHELL — SKETCH: BUNDLE NOZZLE ORIENTATIONS

No.		SHELL SIDE		TUBE SIDE	
25		SHELL SIDE		TUBE SIDE	
26	DESIGN/TEST PRESSURE (barG)				
27	DESIGN TEMPERATURE (°C)				
28	NO. PASSES PER SHELL				
29	CORROSION ALLOWANCE (mm)				
30	NOZZLES: INLET				
31	SIZE & OUTLET				
32	RATING VENT-DRAIN				

33 TUBE NO. ______ O.D. ______ (mm) THK (MIN) (AVG) ______ (mm) LENGTH ______ (m) PITCH ______ (mm) ◁ 30 △ 60 ☐ 90 ◇ 45

34 TUBE TYPE ______ MATERIAL ______

35 SHELL MATL ______ I.D. ______ (mm) O.D. ______ (mm) SHELL COVER MATL ______ (INTEG)(REMOV)

36 CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______

37 TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______

38 FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______

39 BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (mm)

40 BAFFLES--LONG MATL ______ SEAL TYPE ______

41 SUPPORTS--TUBE ______ U-BEND ______ TYPE ______

42 BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______

43 GASKETS--SHELL SIDE ______ -- TUBE SIDE ______

44 --FLOATING HEAD ______

45 ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ◯ TEMA CLASS ______

46 WEIGHT/SHELL ______ (kg) FILLED WITH WATER ______ (kg) BUNDLE ______ (kg)

47 REMARKS: ______

48 ______

49 ______

50 ______

51 ______

52 ______

53 ______

54 ______

55 ______

56 ______

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INTEGRALLY GEARED COMPRESSOR DATASHEET (API 617-9th, Part 3) **SI UNITS (bar)**	JOB NO.		ITEM NO.			
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1	**INTER COOLER(S) - BETWEEN 2nd and 3rd STAGE**			
2	SERVICE OF UNIT:		ITEM NO.	
3	SIZE: TYPE:	☐ HORIZ ☐ VERT	CONNECTED IN	☐ PARALLEL ☐ SERIES
4	SURF/UNIT: (GROSS/EFF) (m²)	SHELLS/UNIT:	SURF/SHELL: (GROSS/EFF)	
5	**PERFORMANCE OF ONE UNIT**			

		SHELL SIDE		TUBE SIDE	
6					
7		SHELL SIDE		TUBE SIDE	
8	○ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (kg/h)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°C)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUID (mPa-s)				
15	☐ SPECIFIC HEAT (kJ/kg °C)				
16	☐ THERMAL CONDUCTIVITY (kJ/m h °C)				
17	☐ LATENT HEAT (kJ/kg °C)				
18	☐ INLET PRESSURE (barG)				
19	○ VELOCITY (m/s)				
20	○ PRESSURE DROP--ALLOW/CALC (bar)				
21	○ FOULING RESISTANCE--MINIMUM (hr m² °C/kJ)				

22	☐ HEAT EXCHANGED	(kJ/hr)	ΔT_{MEAN} CORRECTED	(°C)
23	☐ TRANSFER RATE (kJ/hr m² °C)	SERVICE	CLEAN	

		SHELL SIDE		TUBE SIDE		SKETCH: BUNDLE NOZZLE ORIENTATIONS
24	☐ **CONSTRUCTION OF ONE SHELL**					SKETCH: BUNDLE NOZZLE ORIENTATIONS
25		SHELL SIDE		TUBE SIDE		
26	DESIGN/TEST PRESSURE (barG)					
27	DESIGN TEMPERATURE (°C)					
28	NO. PASSES PER SHELL					
29	CORROSION ALLOWANCE (mm)					
30	NOZZLES: INLET					
31	SIZE & OUTLET					
32	RATING VENT-DRAIN					

33	TUBE NO. O.D. (mm) THK (MIN) (AVG) (mm) LENGTH (m) PITCH (mm) ◁ 30 △ 60 □ 90 ◇ 45
34	TUBE TYPE MATERIAL
35	SHELL MATL I.D. (mm) O.D. (mm) SHELL COVER MATL (INTEG)(REMOV)
36	CHANNEL OR BONNET MATL CHANNEL COVER MATL
37	TUBESHEET--STATIONARY MATL TUBESHEET--FLOATING MATL
38	FLOATING HEAD COVER MATL IMPINGEMENT PROTECTION
39	BAFFLES--CROSS MATL TYPE % CUT (DIA) (AREA) SPACING: C/C INLET (mm)
40	BAFFLES--LONG MATL SEAL TYPE
41	SUPPORTS--TUBE U-BEND TYPE
42	BYPASS SEAL ARRANGEMENT TUBE--TUBESHEET JOINT
43	GASKETS--SHELL SIDE -- TUBE SIDE
44	--FLOATING HEAD
45	ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ○ TEMA CLASS
46	WEIGHT/SHELL (kg) FILLED WITH WATER (kg) BUNDLE (kg)
47	REMARKS:
48	
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51	
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INTEGRALLY GEARED COMPRESSOR
DATASHEET (API 617-9th, Part 3)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 11 OF 12 REQ'N NO. ______

1 **INTER COOLER(S) - BETWEEN 3rd and 4th STAGE**

2 SERVICE OF UNIT: ______ ITEM NO. ______
3 SIZE: ______ TYPE: ______ ☐ HORIZ ☐ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES
4 SURF/UNIT: (GROSS/EFF) ______ (m²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______

5 **PERFORMANCE OF ONE UNIT**

		SHELL SIDE		TUBE SIDE	
6					
7		SHELL SIDE		TUBE SIDE	
8	○ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (kg/h)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°C)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUID (mPa-s)				
15	☐ SPECIFIC HEAT (kJ/kg °C)				
16	☐ THERMAL CONDUCTIVITY (kJ/m h °C)				
17	☐ LATENT HEAT (kJ/kg °C)				
18	☐ INLET PRESSURE (barG)				
19	◎ VELOCITY (m/s)				
20	◎ PRESSURE DROP--ALLOW/CALC (bar)				
21	◎ FOULING RESISTANCE--MINIMUM (hr m² °C/kJ)				

22 ☐ HEAT EXCHANGED ______ (kJ/hr) ΔT_{MEAN} CORRECTED ______ (°C)
23 ☐ TRANSFER RATE (kJ/hr m² °C) SERVICE ______ CLEAN ______

24 ☐ **CONSTRUCTION OF ONE SHELL** — SKETCH: BUNDLE NOZZLE ORIENTATIONS

		SHELL SIDE		TUBE SIDE	
25		SHELL SIDE		TUBE SIDE	
26	DESIGN/TEST PRESSURE (barG)				
27	DESIGN TEMPERATURE (°C)				
28	NO. PASSES PER SHELL				
29	CORROSION ALLOWANCE (mm)				
30	NOZZLES: ______ INLET				
31	SIZE & ______ OUTLET				
32	RATING ______ VENT-DRAIN				

33 TUBE NO. ______ O.D. ______ (mm) THK (MIN) (AVG) ______ (mm) LENGTH ______ (m) PITCH ______ (mm) ◁ 30 △ 60 ☐ 90 ◇ 45
34 TUBE TYPE ______ MATERIAL ______
35 SHELL MATL ______ I.D. ______ (mm) O.D. ______ (mm) SHELL COVER MATL ______ (INTEG)(REMOV)
36 CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______
37 TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______
38 FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______
39 BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (mm)
40 BAFFLES--LONG MATL ______ SEAL TYPE ______
41 SUPPORTS--TUBE ______ U-BEND ______ TYPE ______
42 BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______
43 GASKETS--SHELL SIDE ______ -- TUBE SIDE ______
44 --FLOATING HEAD ______
45 ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ○ TEMA CLASS ______
46 WEIGHT/SHELL ______ (kg) FILLED WITH WATER ______ (kg) BUNDLE ______ (kg)

47 REMARKS: ______
48 ______
49 ______
50 ______
51 ______
52 ______
53 ______
54 ______
55 ______
56 ______

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INTEGRALLY GEARED COMPRESSOR
DATASHEET (API 617-9th, Part 3)
SI UNITS (bar)

JOB NO. ______ ITEM NO. ______
PAGE 12 OF 12 REQ'N NO. ______

1 **INTER COOLER(S) - BETWEEN 4th and 5th STAGE**

2 SERVICE OF UNIT: ______ ITEM NO. ______

3 SIZE: ______ TYPE: ______ ☐ HORIZ ☐ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES

4 SURF/UNIT: (GROSS/EFF) ______ (m²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______

5 **PERFORMANCE OF ONE UNIT**

6

		SHELL SIDE		TUBE SIDE	
7					
8	◯ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (kg/h)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°C)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUID (mPa-s)				
15	☐ SPECIFIC HEAT (kJ/kg °C)				
16	☐ THERMAL CONDUCTIVITY (kJ/m h °C)				
17	☐ LATENT HEAT (kJ/kg °C)				
18	☐ INLET PRESSURE (barG)				
19	◯ VELOCITY (m/s)				
20	◯ PRESSURE DROP--ALLOW/CALC (bar)				
21	◯ FOULING RESISTANCE--MINIMUM (hr m² °C/kJ)				

22 ☐ HEAT EXCHANGED ______ (kJ/hr) ΔT_{MEAN} CORRECTED ______ (°C)

23 ☐ TRANSFER RATE (kJ/hr m² °C) SERVICE ______ CLEAN ______

24 ☐ **CONSTRUCTION OF ONE SHELL** — SKETCH: BUNDLE NOZZLE ORIENTATIONS

		SHELL SIDE		TUBE SIDE	
25					
26	DESIGN/TEST PRESSURE (barG)				
27	DESIGN TEMPERATURE (°C)				
28	NO. PASSES PER SHELL				
29	CORROSION ALLOWANCE (mm)				
30	NOZZLES: INLET				
31	SIZE & OUTLET				
32	RATING VENT-DRAIN				

33 TUBE NO. ______ O.D. ______ (mm THK (MIN) (AVG) ______ (mm) LENGTH ______ (m) PITCH ______ (mm) ◁ 30 △ 60 ☐ 90 ◇ 45

34 TUBE TYPE ______ MATERIAL ______

35 SHELL MATL ______ I.D. ______ (mm) O.D. ______ (mm) SHELL COVER MATL ______ (INTEG)(REMOV)

36 CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______

37 TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______

38 FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______

39 BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (mm)

40 BAFFLES--LONG MATL ______ SEAL TYPE ______

41 SUPPORTS--TUBE ______ U-BEND ______ TYPE ______

42 BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______

43 GASKETS--SHELL SIDE ______ -- TUBE SIDE ______

44 --FLOATING HEAD ______

45 ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ◯ TEMA CLASS ______

46 WEIGHT/SHELL ______ (kg) FILLED WITH WATER ______ (kg) BUNDLE ______ (kg)

47 REMARKS: ______

48

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	BY					
INTEGRALLY GEARED COMPRESSOR DATASHEET (API 617-9th, Part 3) US CUSTOMARY UNITS	REV/APPR					
	JOB NO. ______ ITEM NO. ______					
	PAGE 1 OF 12 REQ'N NO. ______					

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

FOR ______ UNIT ______

SITE ______ SERIAL NO. ______

SERVICE ______ NO. REQUIRED ______

MANUFACTURER ______ DRIVER TYPE ______

MODEL ______ DRIVER ITEM NO. ______

APPLICABLE STANDARD: ○ US ○ ISO

INFORMATION TO BE COMPLETED BY: ○ BY PURCHASER □ BY MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)	NORMAL	OTHER CONDITIONS				
		RATED	**B**	**C**	**D**	**E**
	(NOTE 1)					
○ GAS HANDLED (ALSO SEE PAGE ____)						
△ GAS PROPERTIES						
○ STANDARD VOLUME FLOW (SCFM - 14.7 psia & 60°F DRY)						
○ WEIGHT FLOW (lb/min) ○ WET ○ DRY						
INLET CONDITIONS						
○ PRESSURE (psia)						
○ TEMPERATURE (°F)						
○ RELATIVE HUMIDITY %						
○ MOLECULAR WEIGHT						
□ Cp/Cv (K_1) OR (K_{AVG})						
□ COMPRESSIBILITY (Z_1) OR (Z_{AVG})						
□ INLET VOLUME (cfm) ○ WET ○ DRY						
DISCHARGE CONDITIONS						
○ PRESSURE (psia)						
□ TEMPERATURE (°F) **(ESTIMATED)**						
□ Cp/Cv (K_2) OR (K_{AVG})						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG})						
□ GHP REQUIRED (HP)						
□ TRAIN (BHP) REQUIRED						
□ (BHP) REQUIRED AT DRIVER INCL. EXT. LOSSES (GEAR, ETC.)						
□ SPEED OF DRIVER (rpm)						
□ TURNDOWN (%)						
□ POLYTROPIC HEAD (ft-lb/lb)						
□ POLYTROPIC EFFICIENCY (%)						
○ CERTIFIED POINT						
□ PERFORMANCE CURVE NUMBER						

PROCESS CONTROL

○ METHOD ○ SUCTION THROTTLING ○ VARIABLE INLET ○ SPEED VARIATION ○ DISCHARGE ○ VARIABLE DIFFUSER

FROM ______ (psia) GUIDE VANES FROM ______ % BLOWOFF OR GUIDE VANES

TO ______ (psia) TO ______ % RECIRCULATION

SIGNAL ○ SOURCE ______

TYPE ○ ELECTRONIC ○ PNEUMATIC ○ OTHER ______

RANGE ______ (mA) ______ (psig) ______

REMARKS: NOTE 1: IF GAS ANALYSIS IS GIVEN, MANUFACTURER SHALL SUPPLY GAS PROPERTIES, OTHERWISE DATA SHALL BE SUPPLIED BY USER

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OPERATING CONDITIONS (Continued)

GAS ANALYSIS: ◯ MOL %	MW	NORMAL	OTHER CONDITIONS RATED	B	C	D	E	REMARKS:
AIR	28.966							
OXYGEN	32.000							
NITROGEN	28.016							
WATER VAPOR	18.016							
CARBON MONOXIDE	28.010							
CARBON DIOXIDE	44.010							
HYDROGEN SULFIDE	34.076							
HYDROGEN	2.016							
METHANE	16.042							
ETHYLENE	28.052							
ETHANE	30.068							
PROPYLENE	42.078							
PROPANE	44.094							
I-BUTANE	58.120							
n-BUTANE	58.120							
I-PENTANE	72.146							
n-PENTANE	72.146							
CORROSIVE AGENTS								
TOTAL								
AVG. MOL. WT.								

LOCATION:

◯ INDOOR ◯ OUTDOOR ◯ GRADE

◯ HEATED ◯ UNDER ROOF ◯ MEZZANINE

◯ UNHEATED ◯ PARTIAL SIDES ◯ ______

SITE DATA

◯ ELEVATION ______ (ft) BAROMETER ______ (psia)

◯ RANGE OF AMBIENT TEMPS:

		DRY BULB	WET BULB
NORMAL	(°F)	______	______
MAXIMUM	(°F)	______	______
MINIMUM	(°F)	______	______
______	(°F)	______	______

UNUSUAL CONDITIONS: ◯ DUST ◯ FUMES

______ ______ ______

◯ OTHER ______

______

◯ COPPER AND COPPER ALLOYS PROHIBITED

COATING:

◯ ROTATING COMPONENTS ______

◯ STATIONARY COMPONENTS ______

REMARKS: ______

______

______

______

NOISE SPECIFICATIONS:

◯ APPLICABLE TO MACHINE:

SEE SPECIFICATION ______

◯ APPLICABLE TO NEIGHBORHOOD:

SEE SPECIFICATION ______

ACOUSTIC HOUSING: ◯ YES ◯ NO

APPLICABLE SPECIFICATIONS:

API 617-9th, Part 3

◯ VENDOR HAVING UNIT RESPONSIBILITY

______

◯ GOVERNING SPECIFICATION (IF DIFFERENT)

______

◯ ELEC. AREA CLASS. ◯ NEC ◯ IEC

EQUIPMENT

CLASS ______ GROUP ______ DIV. ______

ZONE ______ GROUP ______ TEMP CLASS ______

CONTROL PANNELS

CLASS ______ GROUP ______ DIV. ______

ZONE ______ GROUP ______ TEMP CLASS ______

◯ INSTRUMENT AND CONTROLS

STANDARD ◯ NEMA ◯ IEC

	INDOOR	OUTDOOR
CONTROL ENCLOSURE	______	______
TERMINAL BOX	______	______

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CONSTRUCTION FEATURES (1 COLUMN PER STAGE, USE ADDITIONAL SHEETS IF NEEDED)

Rotor	Rotor 1					
Stage	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
☐ **CASING:**						
MODEL						
CASING SPLIT						
MATERIAL						
THICKNESS (in.)						
CORROSION ALLOWANCE (in.)						
MAX. ALLOWABLE PRESS (psig)						
TEST PRESS (psig)						
MAX. ALLOWABLE TEMP. (°F)						
MAX. OPERATING TEMP. (°F)						
MIN. OPERATING TEMP. (°F)						
MAX. CASING CAPACITY (icfm)						
☐ **INLET CONNECTIONS**						
TYPE						
ORIENTATION						
FLANGED OR STUDDED?						
MATING FLG & GASKET BY VENDOR?						
GAS VELOCITY (fps)						
☐ **DISCHARGE CONNECTIONS**						
TYPE						
ORIENTATION						
FLANGED OR STUDDED?						
MATING FLG & GASKET BY VENDOR?						
GAS VELOCITY (fps)						
○ **INTERMEDIATE MAIN PROCESS CONNECTIONS**						
DISCH. PRESSURE (psig)						
INLET PRESSURE (psig)						
☐ **ADJUSTABLE INLET GUIDE VANES**						
MATERIAL ______						
NO. INLET GUIDE VANES						
○ BUFFERED ACTUATOR SEAL (Y or N)						
☐ **IMPELLER:**						
DIAMETER						
NUMBER OF VANES						
TYPE (OPEN, ENCLOSED, ETC.)						
TYPE FABRICATION						
MATERIAL						
MIN. YIELD STRENGTH (psi)						
HARDNESS: (Rc) (BRINNEL)						
SMALLEST TIP INTERNAL WIDTH (in.)						
MAX. MACH. NO. @ IMPELLER EYE						
MAX. IMPELLER HEAD @ 100 % SPEED (ft)						
MAX. IMPELLER TIP SPEED (ft/min)						
☐ **DIFFUSER GUIDE VANES**						
ADJUSTABLE?						
MATERIAL						
NO. GUIDE VANES						

REMARKS: ______

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1 **CONSTRUCTION FEATURES, continued (1 COLUMN PER STAGE, USE ADDITIONAL SHEETS IF NEEDED)**

		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
2	☐ **SHAFT SLEEVES:**						
3	MATERIAL						
4	AT SHAFT SEALS?						
5	OTHER LOCATIONS?						
6	**SHAFT SEALS:**						
7	○ SEAL TYPE						
8	○ SETTLE OUT PRESSURE (psig)						
9	○ MINIMUM SEALING PRESSURE (psig)						
10	○ TYPE BUFFER GAS, PRIMARY						
11	☐ PRESSURE (psig)						
12	☐ FLOWRATE (lb/min)						
13	☐ FILTRATION						
14	○ TYPE BUFFER GAS, SECONDARY						
15	☐ PRESSURE (psig)						
16	☐ FLOWRATE (lb/min)						
17	☐ FILTRATION						
18	☐ FLOW RATE TO PROCESS						

19 ○ BUFFER GAS SYSTEM REQUIRED
20 ○ MANIFOLD
21 ○ METHOD OF CONTROL ______
22 ○ BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR
23 ○ PRESSURIZING GAS FOR SUBATMOSPHERIC SEALS ○ EDUCTOR ○ INJECTION
24 ☐ SEAL MANUFACTURER ______ ○ SYSTEM RELIEF VALVE SET PT. ______

25 **BEARING TEMPERATURE DETECTORS**
26 ○ SEE ATTACHED API 670 DATASHEET
27 ○ THERMOCOUPLES TYPE ______
28 ○ RESISTANCE TEMP DETECTORS ______
29 ○ RESISTANCE MATERIAL ______ ○ ______ (ohm)
30 ☐ ALARM TEMPERATURE (°F) ______
31 ☐ SHUTDOWN TEMPERATURE (°F) ______
32 ○ PROVISION FOR LOCAL DISCONNECT
33 ○ LOCATION-JOURNAL BEARING
34 NO. ___ EA PAD ___ EVERY OTHER PAD ___ PER BEARING
35 OTHER ______
36 ○ LOCATION-THRUST BEARING
37 NO. ___ EA PAD ___ EVERY OTHER PAD ___ PER BEARING
38 OTHER ______
39 NO. (INACT) ___ EA PAD ___ EVERY OTHER PAD ___ PER BEARING
40 OTHER ______
41 ○ LOCAL DISCONNECTION
42 ○ MONITOR SUPPLIED BY ______
43 ○ LOCATION ______ ENCLOSURE ______
44 ○ MFR. ______ ☐ MODEL ______
45 ☐ SCALE RANGE ______ ALARM ☐ SET @ ______ (°F)
46 ○ SHUTDOWN: ☐ SET @ ______ (°F) ○ TIME DELAY ______ (sec)
47 **KEY PHASOR REQUIRED**
48 ○ COMPRESSOR ○ GEAR H.S. ○ GEAR L.S.

25 **VIBRATION DETECTORS:** ○ SEE ATTACHED API 670 DATASHEET
26 ○ TYPE ______ ☐ MODEL ______
27 ○ MFR ______
28 ○ NO. AT EA SHAFT BEARING ______ TOTAL NO. ______
29 ○ OSCILLATOR-DETECTORS SUPPLIED BY ______
30 ○ MFR ______ ☐ MODEL ______
31 ○ MONITOR SUPPLIED BY ______
32 ○ LOCATION ______ ENCLOSURE ______
33 ○ MFR. ______ ☐ MODEL ______
34 ☐ SCALE RANGE ______ ALARM ☐ SET @ ______ (mil)
35 ○ SHUTDOWN: ☐ SET @ ______ (mil) ○ TIME DELAY ______ (sec)
36 ○ CASING VIBRATION TRANSDUCERS
37 ○ CASING VIBRATION MONITORS
38 **AXIAL POSITION/VIBRATION DETECTOR:**
39 ○ SEE ATTACH. API 670 DATASHEET
40 ○ TYPE ______ ☐ MODEL ______
41 ○ MFR ______ ○ NO. REQUIRED ______
42 ○ OSCILLATOR-DEMODULATOR SUPPLIED BY ______
43 ○ MFR ______ ☐ MODEL ______
44 ○ MONITOR SUPPLIED BY ______
45 ○ LOCATION ______ ENCLOSURE ______
46 ○ MFR. ______ ☐ MODEL ______
47 ☐ SCALE RANGE ______ ALARM ☐ SET @ ______ (mil)
48 ○ SHUTDOWN: ☐ SET @ ______ (mil) ○ TIME DELAY ______ (sec)

49 **REMARKS:** ______
50 ______
51 ______
52 ______
53 ______
54 ______
55 ______
56 ______

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CONSTRUCTION FEATURES, ROTORS (1 COLUMN PER ROTOR, USE ADDITIONAL SHEETS IF NEEDED)

☐ **DRIVER SPEEDS:**
MAX. CONT. ______
TRIP SPEED ______

PITCH LINE VELOCITY (fps) ______
NORMAL DIAMETRAL PITCH ______
HELIX ANGLE ______ PRESSURE ANGLE ______

☐ **ROTOR NUMBER**	BULL GEAR	ROTOR 1	ROTOR 2	ROTOR 3	ROTOR 4
SPEED (rpm)					
SERVICE POWER (HP)					
SERVICE FACTOR					
NUMBER OF TEETH					
FACE WIDTH (in.)					
AGMA GEOMETRY FACTOR "J"					
AGMA GEOMETRY FACTOR "I"					
MINIMUM HARDNESS (Rc)					
ROTOR WEIGHT (INC WHEELS) (lb)					
BACKLASH (in.)					
GEARBOX FULL LOAD POWER LOSS					
☐ **LATERAL CRITICAL SPEEDS (DAMPED)**					
FIRST CRITICAL					
SECOND CRITICAL					
THIRD CRITICAL					
FOURTH CRITICAL					

○ LATERAL ANALYSIS ADDITIONAL REQUIREMENTS
○ TRAIN LATERAL ANALYSIS REQUIRED
○ TORSIONAL ANALYSIS REQUIRED

☐ **TORSIONAL CRITICAL SPEEDS:**	
FIRST CRITICAL	
SECOND CRITICAL	
THIRD CRITICAL	
FOURTH CRITICAL	

○ LIST OF TRAIN UNDESIRABLE SPEEDS
○ STABILITY ANALYSIS

☐ **VIBRATION:**					
ALLOWABLE RADIAL TEST LEVEL (mils P-P)					
ALLOWABLE AXIAL TEST LEVEL (mils P-P)					
AXIAL DISPLACEMENT LIMIT (mils)					

☐ **BALANCE PISTON:**				
MATERIAL				
FIXATION METHOD				
NORMAL CLEARANCE (in.)				
AREA (in.²)				
FLOW, NORMAL CLEARANCE (lb/min)				
FLOW, 2x NORMAL CLEAR (lb/min)				
○ PRESS. CONN. BAL LINE				

REMARKS:

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CONSTRUCTION FEATURES, ROTOR BEARINGS (1 COLUMN PER ROTOR, USE ADDITIONAL SHEETS IF NEEDED)

RADIAL BEARINGS, DRIVE END	BULL GEAR	ROTOR 1	ROTOR 2	ROTOR 3	ROTOR 4
☐ TYPE					
☐ MANUFACTURER					
☐ LENGTH (in.)					
☐ SHAFT DIAMETER (in.)					
☐ UNIT LOAD (ACT/ALLOW)					
☐ BASE MATERIAL					
☐ NUMBER OF PADS					
☐ LOAD: BETWEEN/ON PAD					
☐ PIVOT: CENTER/OFFSET, %					
☐ RADIAL BEARING SPAN					
☐					
RADIAL BRG, OPPOSITE DRIVE END					
☐ TYPE					
☐ MANUFACTURER					
☐ LENGTH (in.)					
☐ SHAFT DIAMETER (in.)					
☐ UNIT LOAD (ACT/ALLOW)					
☐ BASE MATERIAL					
☐ NUMBER OF PADS					
☐ LOAD: BETWEEN/ON PAD					
☐ PIVOT: CENTER/OFFSET, %					
☐					
THRUST BEARINGS , ACTIVE					
☐ TYPE					
☐ MANUFACTURER					
☐ UNIT LOADING (max) (psi)					
☐ UNIT LOAD (ULT.) (psi)					
☐ AREA ($in.^2$)					
☐ NUMBER OF PADS					
☐ PIVOT: CENTER / OFFSET, %					
☐ PAD BASE MATERIAL					
○ COPPER BACKED PERMITTED?					
☐ COLLAR MATERIAL					
☐ INTEGRAL OR REPLACEABLE COLLAR?					
☐ SIZING CRITERIA					
☐ FLOODED OR DIRECTED LUBRICATION?					
THRUST BEARINGS , INACTIVE					
☐ TYPE					
☐ MANUFACTURER					
☐ UNIT LOADING (max) (psi)					
☐ UNIT LOAD (ULT.) (psi)					
☐ AREA ($in.^2$)					
☐ NUMBER OF PADS					
☐ PIVOT: CENTER / OFFSET, %					
☐ PAD BASE MATERIAL					
○ COPPER BACKED PERMITTED?					
☐ COLLAR MATERIAL					
☐ INTEGRAL OR REPLACEABLE COLLAR?					
☐ SIZING CRITERIA					
☐ FLOODED OR DIRECTED LUBRICATION?					

REMARKS:

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1 ☐ OTHER CONNECTIONS

	SERVICE:	NO.	SIZE	TYPE		NO.	SIZE	TYPE
3	☐ LUBE-OIL INLET				☐ PRESSURE			
4	☐ LUBE OIL OUTLET				☐ TEMPERATURE			
5	☐ SEAL-OIL INLET				☐ SOLVENT INJECTION			
6	☐ SEAL-OIL OUTLET				☐ PURGE FOR:			
7	☐ SEAL GAS INLET				☐ BRG. HOUSING			
8	☐ SEAL GAS OUTLET				☐ BTWN BRG & SEAL			
9	☐ CASING DRAINS				☐ BTWN SEAL & GAS			
10	☐ STAGE DRAINS				______			

11 ○ INDIVIDUAL STAGE DRAINS REQUIRED
12 ○ VALVED & BLINDED
13 ○ VALVED & BLINDED & MANIFOLD

14 **LUBRICATION AND SEALING SYSTEMS**

15 ○ SEE ATTACHED API 614 DATASHEET
16 ○ SEPARATE ○ COMBINED
17 ○ INTEGRAL OIL RESERVOIR
18 △ OIL TYPE

19 **ACCESSORIES**

20 **COUPLING AND GUARDS**
21 NOTE: SEE ROTATING ELEMENTS - SHAFT ENDS
22 ○ SEE ATTACHED API 671 DATASHEET ○ KEYLESS HYDRAULIC ○ KEYED ○ FLANGED ○ OTHER ______
23 COUPLING FURNISHED BY ______ MOUNTED BY ______
24 MANUFACTURER ______ TYPE ______ MODEL ______
25 COUPLING GUARD FURNISHED BY: ______
26 TYPE: ○ FULLY ENCLOSED ○ SEMI-OPEN ○ OTHER ______

27 **COUPLING DETAILS**
28 ☐ MAX O.D. ______ (in.) ○ PLUG AND RING GAUGES ○ LAPPING TOOL
29 ☐ HUB WEIGHT ______ (lbm) COOLING REQUIREMENTS:
30 ☐ SPACER LENGTH ______ (in.) ☐ FLOWRATE ______ (gpm)
31 ☐ SPACER WEIGHT ______ (lbm)

32 **MOUNTING PLATES**

33 ○ BASEPLATES FURNISHED BY ______ ○ SOLEPLATES FURNISHED BY ______
34 ○ COMPRESSOR ONLY ○ DRIVER ○ GEAR ☐ THICKNESS ______ (in.)
35 ○ OTHER ______ ○ ______
36 ○ NONSKID DECKING ○ SLOPED DECK
37 △ LEVELING PADS OR TARGETS ☐ STAINLESS STEEL SHIM THICKNESS ______ (in.)
38 △ COLUMN MOUNTING
39 ○ SUBSOLE PLATES REQUIRED
40 ☐ STAINLESS STEEL SHIM THICKNESS ______ (in.) ○ COUNTER BORE ANCHOR BOLT HOLES
41 ○ MACHINED MOUNTING PADS REQUIRED

42 ANTI-SURGE SYSTEM FURNISHED BY ○ PURCHASER ☐ VENDOR
43 ○ ☐ ANTI-SURGE VALVE ○ SIZING ONLY
44 PRESSURE UPSTREAM: ______ (psig) DOWNSTREAM: ______ (psig)
45 ☐ Δ P VALVE ______ (psi) STROKE TIME OPEN - CLOSE ______ (sec)

47 ○ ☐ RECIRCULATION VALVE ○ SIZING ONLY
48 ○ ☐ BLOWOFF VALVE ○ SIZING ONLY
49 ○ ☐ CONTROL SYSTEM
50 ○ ☐ PIPING
51 ○ ☐ FLOW ELEMENT
52 ○ ☐ ______ ○ ☐ ______
53 ○ ☐ ______ ○ ☐ ______
54 ○ ☐ ______ ○ ☐ ______
55 ○ ☐ ______ ○ ☐ ______
56 ○ ☐ ______ ○ ☐ ______

REMARKS: ______

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#		
1	**UTILITIES**	
2	○ **UTILITY CONDITIONS:**	**MANUALS**
3	**STEAM:** **DRIVERS**	○ DRAFT MANUAL FOR REVIEW
4	INLET MIN ____ (psig) ____ (°F)	○ TECHNICAL DATA MANUAL
5	NORM ____ (psig) ____ (°F)	**MISCELLANEOUS:**
6	MAX ____ (psig) ____ (°F)	☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
7	EXHAUST. MIN ____ (psig) ____ (°F)	BEFORE SUCTION ____
8	NORM ____ (psig) ____ (°F)	○ COMPRESSOR TO BE SUITABLE FOR FIELD RUN-IN ON AIR
9	MAX ____ (psig) ____ (°F)	○ PROVISION FOR LIQUID INJECTION ____
10	**ELECTRICITY:**	○ INJECTION MANIFOLD
11	DRIVERS / CONTROL / SHUTDOWN	○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEMS
12	VOLTAGE ____ ____ ____	○ VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING/FOUNDATION
13	HERTZ ____ ____ ____	○ SHOP FIT-UP OF VENDOR PROCESS PIPING
14	PHASE ____ ____ ____	○ WELDING HARDNESS TESTING
15	○ REDUCED VOLTAGE START	____
16	△ NUMBER OF STARTS ____	○ DESIGN AUDIT
17	○ **INSTRUMENT AIR:**	○ BALANCE PISTON ΔP
18	MAX PRESS ____ (psig) MIN PRESS ____ (psig)	○ PROVIDE TAIL END SCHEDULES
19	☐ **ROTATION, VIEWED OPP. DRIVE END** ○ **CW** ○ **CCW**	○ BOROSCOPIC INSPECTION PORTS
20	**SHOP INSPECTION AND TESTS:**	**VENDOR'S REPRESENTATIVE SHALL**
21	○ (SEE INSPECTOR'S CHECKLIST) — REQ'D / WIT/OBV	○ OBSERVE FLANGE PARTING
22	HYDROSTATIC ● ____	○ CHECK ALIGNMENT AT TEMPERATURE
23	IMPELLER OVERSPEED ● ____	○ BE PRESENT AT INITIAL ALIGNMENT
24	MECHANICAL RUN ● ____	☐ **WEIGHTS:** (lbm)
25	○ CONTRACT COUPLING ○ IDLING ADAPTOR(S)	COMPR. ____ GEAR ____ DRIVER ____ BASE ____
26	○ CONTRACT PROBES ○ SHOP PROBES	ROTORS: COMPR. ____ DRIVER ____ GEAR ____
27	○ PURCHASER VIB. EQUIPMENT	COMPRESSOR UPPER CASE ____
28	VARY LUBE OIL PRESSURES & TEMPERATURES ○ ____	MAX. FOR MAINTENANCE (IDENTIFY) ____
29	REASSEMBLY CHECK BALANCE ○ ____	TOTAL SHIPPING WEIGHT ____
30	POLAR FORM VIB DATA ○ ____	
31	RECORD VIB DATA ○ ____	☐ **SPACE REQUIREMENTS:** (in.)
32	SHAFT END SEAL INSP ○ ____	COMPLETE UNIT: L ____ W ____ H ____
33	GAS LEAK TEST AT DISCH PRESS ○ ____	
34	○ POST TEST INTERNAL INSP	**SPECIAL TOOL PACKAGING**
35	○ BEFORE GAS LEAKAGE TEST	○ METAL STORAGE CONTAINER
36	○ AFTER GAS LEAKAGE TEST ○ ____	○ OTHER: ____
37	PERFORMANCE TEST ○ ____	
38	COMPLETE UNIT TEST ○ ____	**PAINTING:**
39	TANDEM TEST ○ ____	○ MANUFACTURER'S STD.
40	GEAR TEST ○ ____	○ OTHER ____
41	HELIUM LEAK TEST ○ ____	**NAMEPLATE** ○ U.S. CUSTOMARY ○ METRIC
42	SOUND LEVEL TEST ○ ____	**SHIPMENT:**
43	AUX. EQUIPMENT TEST ____ ○ ____	○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQ'D.
44	FULL LOAD / SPEED / PRESS TEST ○ ____	○ OUTDOOR STORAGE MORE THAN 6 MONTHS ____ MO
45	HYDRAULIC COUPLING FIT INSP ○ ____	SPARE ROTOR ASSEMBLY PACKAGE ○ DGS REMOVED FOR SHIPMENT
46	SPARE PARTS TEST ____ ○ ____	○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
47	INSPECTOR'S CHECKLIST COMPLIANCE ○ ____	○ METAL STORAGE CONTAINER
48	GAS SEAL TEST VENDOR SHOP ○ ____	○ N2 PURGE ○ OTHER: ____
49	**MATERIALS INSPECTION REQUIREMENTS**	
50	○ RADIOGRAPHY REQUIRED FOR ____	○ LOW TEMPERATURE
51	○ ULTRASONIC REQUIRED FOR ____	MIN. DESIGN METAL TEMPERATURE ____ (°F)
52	○ MAGNETIC PARTICLE REQUIRED FOR ____	AT CONCURRANT PRESSURE ____ (psig)
53	○ LIQUID PENETRANT REQUIRED FOR ____	○ OTHER TRAIN COMPONENTS
54		○ Q.C. OF INACCESSIBLE WELDS
55	**REMARKS:** ____	
56		

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PAGE 9 OF 12 REQ'N NO. ______

1	**INTER COOLER(S) - BETWEEN 1st and 2nd STAGE**
2	SERVICE OF UNIT: ______ ITEM NO. ______
3	SIZE: ______ TYPE: ______ ☐ HORIZ ☐ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES
4	SURF/UNIT: (GROSS/EFF) ______ (ft²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______
5	**PERFORMANCE OF ONE UNIT**
6	

		SHELL SIDE		TUBE SIDE	
7					
8	○ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (lbm/hr)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°F)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUID (cP)				
15	☐ SPECIFIC HEAT (BTU/lb °F)				
16	☐ THERMAL CONDUCTIVITY (Btu/ft h °F)				
17	☐ LATENT HEAT (BTU/lb °F)				
18	☐ INLET PRESSURE (psig)				
19	◎ VELOCITY (fps)				
20	◎ PRESSURE DROP--ALLOW/CALC (psi)				
21	◎ FOULING RESISTANCE--MINIMUM (hr ft²°F/BTU)				

22	☐ HEAT EXCHANGED ______ (BTU/hr) ΔT_{MEAN} CORRECTED ______ (°F)
23	☐ TRANSFER RATE (BTU/hr ft² °F) SERVICE ______ CLEAN ______

	☐ CONSTRUCTION OF ONE SHELL	SHELL SIDE		TUBE SIDE	
24					
25					
26	DESIGN/TEST PRESSURE (psig)				
27	DESIGN TEMPERATURE (°F)				
28	NO. PASSES PER SHELL				
29	CORROSION ALLOWANCE (in.)				
30	NOZZLES: INLET				
31	SIZE & OUTLET				
32	RATING VENT-DRAIN				

SKETCH: BUNDLE NOZZLE ORIENTATIONS

33	TUBE NO. ______ O.D. ______ (in.) THK (MIN) (AVG) ______ (in.) LENGTH ______ (ft) PITCH ______ (in.) ◁ 30 △ 60 □ 90 ◇ 45
34	TUBE TYPE ______ MATERIAL ______
35	SHELL MATL ______ I.D. ______ (in.) O.D. ______ (in.) SHELL COVER MATL ______ (INTEG)(REMOV)
36	CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______
37	TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______
38	FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______
39	BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (in.)
40	BAFFLES--LONG MATL ______ SEAL TYPE ______
41	SUPPORTS--TUBE ______ U-BEND ______ TYPE ______
42	BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______
43	GASKETS--SHELL SIDE ______ -- TUBE SIDE ______
44	--FLOATING HEAD ______
45	ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ○ TEMA CLASS ______
46	WEIGHT/SHELL ______ (lbm) FILLED WITH WATER ______ (lbm) BUNDLE ______ (lbm)
47	REMARKS: ______
48	
49	
50	
51	
52	
53	
54	
55	
56	

REVISION	0	1	2	3	4
DATE					

INTEGRALLY GEARED COMPRESSOR DATASHEET (API 617-9th, Part 3)
US CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
PAGE 10 OF 12 REQ'N NO. ______

1 INTER COOLER(S) - BETWEEN 2nd and 3rd STAGE
2 SERVICE OF UNIT: ______ ITEM NO. ______
3 SIZE: ______ TYPE: ______ ☐ HORIZ ■ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES
4 SURF/UNIT: (GROSS/EFF) ______ (ft²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______
5 PERFORMANCE OF ONE UNIT
6

7		SHELL SIDE		TUBE SIDE	
8	○ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (lbm/hr)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°F)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUIE (cP)				
15	☐ SPECIFIC HEAT (BTU/lb °F)				
16	☐ THERMAL CONDUCTIVITY (Btu/ft h °F)				
17	☐ LATENT HEAT (BTU/lb °F)				
18	☐ INLET PRESSURE (psig)				
19	○ VELOCITY (fps)				
20	○ PRESSURE DROP--ALLOW/CALC (psi)				
21	○ FOULING RESISTANCE--MINIMUM (hr ft²°F/BTU)				

22 ☐ HEAT EXCHANGED ______ (BTU/hr) ΔT_{MEAN} CORRECTED ______ (°F)
23 ☐ TRANSFER RATE (BTU/hr ft² °F) SERVICE ______ CLEAN ______

24 ☐ CONSTRUCTION OF ONE SHELL — SKETCH: BUNDLE NOZZLE ORIENTATIONS

25		SHELL SIDE		TUBE SIDE	
26	DESIGN/TEST PRESSURE (psig)				
27	DESIGN TEMPERATURE (°F)				
28	NO. PASSES PER SHELL				
29	CORROSION ALLOWANCE (in.)				
30	NOZZLES: ______ INLET				
31	SIZE & ______ OUTLET				
32	RATING ______ VENT-DRAIN				

33 TUBE NO. ______ O.D. ______ (in.) THK (MIN) (AVG) ______ (in.) LENGTH ______ (ft) PITCH ______ (in.) ◁ 30 △ 60 □ 90 ◇ 45
34 TUBE TYPE ______ MATERIAL ______
35 SHELL MATL ______ I.D. ______ (in.) O.D. ______ (in.) SHELL COVER MATL ______ (INTEG)(REMOV)
36 CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______
37 TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______
38 FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______
39 BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (in.)
40 BAFFLES--LONG MATL ______ SEAL TYPE ______
41 SUPPORTS--TUBE ______ U-BEND ______ TYPE ______
42 BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______
43 GASKETS--SHELL SIDE ______ -- TUBE SIDE ______
44 --FLOATING HEAD ______
45 ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ○ TEMA CLASS ______
46 WEIGHT/SHELL ______ (lbm) FILLED WITH WATER ______ (lbm) BUNDLE ______ (lbm)
47 REMARKS: ______
48
49
50
51
52
53
54
55
56

REVISION	0	1	2	3	4
DATE					

INTEGRALLY GEARED COMPRESSOR
DATASHEET (API 617-9th, Part 3)
US CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
PAGE 11 OF 12 REQ'N NO. ______

1 **INTER COOLER(S) - BETWEEN 3rd and 4th STAGE**

2 SERVICE OF UNIT: ______ ITEM NO. ______
3 SIZE: ______ TYPE: ______ ☐ HORIZ ☐ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES
4 SURF/UNIT: (GROSS/EFF) ______ (ft²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______

5 **PERFORMANCE OF ONE UNIT**

6

			SHELL SIDE		TUBE SIDE	
7			SHELL SIDE		TUBE SIDE	
8	○ FLUID NAME					
9	☐ MASS FLOW RATE, TOTAL	(lbm/hr)				
10	VAPOR--IN/OUT					
11	LIQUID--IN/OUT					
12	☐ TEMPERATURE--IN/OUT	(°F)				
13	☐ SPECIFIC GRAVITY					
14	☐ VISCOSITY, LIQUID	(cP)				
15	☐ SPECIFIC HEAT	(BTU/lb °F)				
16	☐ THERMAL CONDUCTIVITY	(Btu/ft h °F)				
17	☐ LATENT HEAT	(BTU/lb °F)				
18	☐ INLET PRESSURE	(psig)				
19	○ VELOCITY	(fps)				
20	○ PRESSURE DROP--ALLOW/CALC	(psi)				
21	○ FOULING RESISTANCE--MINIMUM	(hr ft²°F/BTU)				

22 ☐ HEAT EXCHANGED ______ (BTU/hr) ΔT_{MEAN} CORRECTED ______ (°F)
23 ☐ TRANSFER RATE (BTU/hr ft² °F) SERVICE ______ CLEAN ______

24 ☐ **CONSTRUCTION OF ONE SHELL** SKETCH: BUNDLE NOZZLE ORIENTATIONS

			SHELL SIDE		TUBE SIDE	
25			SHELL SIDE		TUBE SIDE	
26	DESIGN/TEST PRESSURE	(psig)				
27	DESIGN TEMPERATURE	(°F)				
28	NO. PASSES PER SHELL					
29	CORROSION ALLOWANCE	(in.)				
30	NOZZLES:	INLET				
31	SIZE &	OUTLET				
32	RATING	VENT-DRAIN				

33 TUBE NO. ______ O.D. ______ (in.) THK (MIN) (AVG) ______ (in.) LENGTH ______ (ft) PITCH ______ (in.) ◁ 30 △ 60 ☐ 90 ◇ 45
34 TUBE TYPE ______ MATERIAL ______
35 SHELL MATL ______ I.D. ______ (in.) O.D. ______ (in.) SHELL COVER MATL ______ (INTEG)(REMOV)
36 CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______
37 TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______
38 FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______
39 BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (in.)
40 BAFFLES--LONG MATL ______ SEAL TYPE ______
41 SUPPORTS--TUBE ______ U-BEND ______ TYPE ______
42 BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______
43 GASKETS--SHELL SIDE ______ -- TUBE SIDE ______
44 --FLOATING HEAD ______
45 ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ○ TEMA CLASS ______
46 WEIGHT/SHELL ______ (lbm) FILLED WITH WATER ______ (lbm) BUNDLE ______ (lbm)

47 REMARKS: ______
48 ______
49 ______
50 ______
51 ______
52 ______
53 ______
54 ______
55 ______
56 ______

	REVISION	0	1	2	3	4
	DATE					
INTEGRALLY GEARED COMPRESSOR DATASHEET (API 617-9th, Part 3) US CUSTOMARY UNITS	JOB NO. ______ ITEM NO. ______					
	PAGE 12 OF 12 REQ'N NO. ______					

1 **INTER COOLER(S) - BETWEEN 4th and 5th STAGE**

2 SERVICE OF UNIT: ______ ITEM NO. ______

3 SIZE: ______ TYPE: ______ ☐ HORIZ ☐ VERT CONNECTED IN ☐ PARALLEL ☐ SERIES

4 SURF/UNIT: (GROSS/EFF) ______ (ft²) SHELLS/UNIT: ______ SURF/SHELL: (GROSS/EFF) ______

5 **PERFORMANCE OF ONE UNIT**

6

		SHELL SIDE		TUBE SIDE	
7					
8	○ FLUID NAME				
9	☐ MASS FLOW RATE, TOTAL (lbm/hr)				
10	VAPOR--IN/OUT				
11	LIQUID--IN/OUT				
12	☐ TEMPERATURE--IN/OUT (°F)				
13	☐ SPECIFIC GRAVITY				
14	☐ VISCOSITY, LIQUID (cP)				
15	☐ SPECIFIC HEAT (BTU/lb °F)				
16	☐ THERMAL CONDUCTIVITY (Btu/ft h °F)				
17	☐ LATENT HEAT (BTU/lb °F)				
18	☐ INLET PRESSURE (psig)				
19	◙ VELOCITY (fps)				
20	◙ PRESSURE DROP--ALLOW/CALC (psi)				
21	◙ FOULING RESISTANCE--MINIMUM (hr ft²°F/BTU)				

22 ☐ HEAT EXCHANGED ______ (BTU/hr) ΔT_{MEAN} CORRECTED ______ (°F)

23 ☐ TRANSFER RATE (BTU/hr ft² °F) SERVICE ______ CLEAN ______

24 ☐ **CONSTRUCTION OF ONE SHELL** — SKETCH: BUNDLE NOZZLE ORIENTATIONS

		SHELL SIDE		TUBE SIDE	
25					
26	DESIGN/TEST PRESSURE (psig)				
27	DESIGN TEMPERATURE (°F)				
28	NO. PASSES PER SHELL				
29	CORROSION ALLOWANCE (in.)				
30	NOZZLES: ______ INLET				
31	SIZE & ______ OUTLET				
32	RATING ______ VENT-DRAIN				

33 TUBE NO. ______ O.D. ______ (in.) THK (MIN) (AVG) ______ (in.) LENGTH ______ (ft) PITCH ______ (in.) ◁ 30 △ 60 □ 90 ◇ 45

34 TUBE TYPE ______ MATERIAL ______

35 SHELL MATL ______ I.D. ______ (in.) O.D. ______ (in.) SHELL COVER MATL ______ (INTEG)(REMOV)

36 CHANNEL OR BONNET MATL ______ CHANNEL COVER MATL ______

37 TUBESHEET--STATIONARY MATL ______ TUBESHEET--FLOATING MATL ______

38 FLOATING HEAD COVER MATL ______ IMPINGEMENT PROTECTION ______

39 BAFFLES--CROSS MATL ______ TYPE ______ % CUT (DIA) (AREA) ______ SPACING: C/C ______ INLET ______ (in.)

40 BAFFLES--LONG MATL ______ SEAL TYPE ______

41 SUPPORTS--TUBE ______ U-BEND ______ TYPE ______

42 BYPASS SEAL ARRANGEMENT ______ TUBE--TUBESHEET JOINT ______

43 GASKETS--SHELL SIDE ______ -- TUBE SIDE ______

44 --FLOATING HEAD ______

45 ASME SECTION VIII CODE REQUIREMENTS: ☐ DESIGN & TEST ☐ STAMP ☐ NOT APPLICABLE ○ TEMA CLASS ______

46 WEIGHT/SHELL ______ (lbm) FILLED WITH WATER ______ (lbm) BUNDLE ______ (lbm)

47 REMARKS: ______

48 ______

49 ______

50 ______

51 ______

52 ______

53 ______

54 ______

55 ______

56 ______

Annex B
(informative)

Vendor Drawing and Data Requirements

B.1 VDDR for Integrally Geared Compressors (See Text for Details of the Description)

INTEGRALLY GEARED COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]— Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Supplier [b c]	Review Received from Supplier	Review Returned to Supplier	Final due From Supplier [c]	Final Received from Supplier
/	/	/	1. Certified dimensional outline drawing and list of connections					
/	/	/	2. Cross-sectional drawings and part numbers					
/	/	/	3. Rotor assembly drawings and part numbers					
/	/	/	4. Thrust-bearing assembly drawings and part numbers					
/	/	/	5. Journal-bearing assembly drawings and bill of materials					
/	/	/	6. Coupling assembly drawings and bill of materials					
/	/	/	7. Lube-oil schematic and bill of materials					
/	/	/	8. Lube-oil arrangement drawing and list of connections					
/	/	/	9. Lube-oil component drawings and data					
/	/	/	10. Seal system schematic and bill of material					

The last five columns are headed **Distribution Record**.

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

INTEGRALLY GEARED COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]— Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Supplier [b c]	Review Received from Supplier	Review Returned to Supplier	Final due From Supplier [c]	Final Received from Supplier
/	/	/	11. Seal system arrangement drawing and list of connections					
/	/	/	12. Seal system component drawings and data					
/	/	/	13. Seal assembly drawing and part numbers					
/	/	/	14. Electrical and instrumentation schematics and bill of materials					
/	/	/	15. Electrical and instrumentation arrangement drawing and list of connections					
/	/	/	16. Buffer gas system schematic and bill of material					
/	/	/	17. Buffer gas system arrangement drawing and list of connections					
/	/	/	18. Buffer gas system component drawing and data					
/	/	/	19. Datasheets (proposal/as-built)					
/	/	/	20. Allowable external forces and moments for each nozzle in tabular form (with proposal)					
/	/	/	21. Gear quality documentations					

Distribution Record applies to the last five columns.

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

INTEGRALLY GEARED COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Supplier [b c]	Review Received from Supplier	Review Returned to Supplier	Final Due from Supplier [c]	Final Received from Supplier
/	/	/	22. Gear tooth contact check results					
/	/	/	23. Certificates for gear materials					
/	/	/	24. Predicted noise sound level (proposal)					
/	/	/	25. Metallurgy of major components (in proposal)					
/	/	/	26. Lateral analysis report and stability analysis (if required)					
/	/	/	27. Torsional analysis report					
/	/	/	28. Vibration analysis report					
/	/	/	29. Performance curves for each compressor section (proposal/as-built)					
/	/	/	30. Impeller overspeed test report					
/	/	/	31. Mechanical running test report					
/	/	/	32. Coupling selection and rating					

Distribution Record: Review Due from Supplier; Review Received from Supplier; Review Returned to Supplier; Final Due from Supplier; Final Received from Supplier.

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

INTEGRALLY GEARED COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.

			Description (see text)	**Distribution Record**				
				Review Due from Supplier [b c]	Review Received from Supplier	Review Returned to Supplier	Final Due from Supplier [c]	Final Received from Supplier
/	/	/	33. List of recommended spare parts					
/	/	/	34. List of special tools					
/	/	/	35. Preparation for storage at job site before installation					
/	/	/	36. Weather protection and winterization required at job site					
/	/	/	37. Tabulation of all utilities					
/	/	/	38. List of similar machines					
/	/	/	39. Operating restrictions to protect equipment during start-up operation and shutdown					
/	/	/	40. List of components requiring purchaser's approval					
/	/	/	41. Summary of materials and hardness of materials exposed to H_2S					
/	/	/	42. Seal leakage rates					
/	/	/	43. Interstage cooler system data					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

INTEGRALLY GEARED COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Supplier shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	**Distribution Record** Review Due from Supplier [b c]	Review Received from Supplier	Review Returned to Supplier	Final Due from Supplier [c]	Final Received from Supplier
/	/	/	44. Drawings, details, and description of instrumentation and controls					
/	/	/	45. Minimum length of straight pipe required at machine inlet or side inlets					
/	/	/	46. Maximum and minimum allowable seal pressure for each compressor					
/	/	/	47. Statement of manufacturer's testing capabilities					
/	/	/	48. Performance test data and curves					
/	/	/	49. Back-to-back impeller machine supplier to provide thrust-bearing loads vs differential pressure curve					
/	/	/	50. Production delivery schedule					
/	/	/	51. Testing procedures					
/	/	/	52. Progress reports					
/	/	/	53. Installation manual					
/	/	/	54. Operating and maintenance manual					
/	/	/	55. Technical data manual					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

INTEGRALLY GEARED COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS	Job No.	Item No.
	Purchase Order No.	Date
	Requisition No.	Date
	Inquiry No.	Date
	Revision by	Manufacturer
	For	Unit
	Site	Service

1. Where necessary to meet the scheduled shipping date, the supplier shall proceed with manufacture upon receipt of the order and without awaiting the purchaser's approval of drawings.

2. The supplier shall send all drawings and data to the following:

____

____

____

3. All drawings and data shall show project, purchase order, and item numbers as well as plant location and unit. One set of the drawings and instructions necessary for field installation, in addition to the copies specified above, shall be forwarded with shipment.

4. See the descriptions of required items that follow.

5. All of the information indicated on the distribution schedule shall be received before final payment is made.

6. If typical drawings, schematics, and bills of material are used for proposals, they shall be marked up to show the expected weight and dimensions to reflect the actual equipment and scope proposed.

Nomenclature:

S number of weeks before shipment

F number of weeks after firm order

D number of weeks after receipt of approved drawings

Supplier____

Date________________ Supplier Reference ________________________

Signature____

(Signature acknowledges receipt of all instructions)

B.2 Descriptions

1) Certified dimensional outline drawing and list of connections, including the following:
   a) the size, rating, and location of all customer connections;
   b) approximate overall and handling weights;
   c) overall dimensions and maintenance and dismantling clearances;
   d) shaft centering height;
   e) dimensions of baseplate (if furnished) for train or skid mounted package, complete with diameters, number and locations of bolt holes, and thicknesses of sections through which the bolts pass;
   f) grounding details;
   g) forces and moments allowed for suction and discharge nozzles;
   h) center of gravity and lifting points;
   i) shaft end separation and alignment data;
   j) direction of rotation;
   k) winterization, tropicalization, and/or noise attenuation details, when required;
   l) sketches to show lifting of assembled machine and major components and auxiliaries.
2) Cross-sectional drawings and part numbers of major equipment.
3) Rotor assembly drawings and part numbers.
4) Thrust-bearing assembly drawings and part numbers.
5) Journal-bearing assembly drawings and bill of materials.
6) Coupling assembly drawing and bill of materials.
7) Lube-oil schematic and bill of material, including the following:
   a) oil flows, temperatures, and pressure at each point;
   b) control alarm shutdown settings for pressure and temperature;
   c) total heat loads;
   d) utility requirements, including electrical, water, air, and steam;
   e) pipe, valve, and orifice sizes;
   f) instrumentation, safety devices, control schemes, and wiring diagrams.
8) Lube-oil arrangement drawing and list of connections.

9) Lube-oil component drawings and data, including the following:

   a) pumps and drivers;

   b) heat exchangers, filter, and reservoir;

   c) instrumentation.

10) Seal system schematic and bill of material, including the following:

    a) flows oil or gas, temperatures, and pressures at each point;

    b) control, alarm, and shutdown settings for pressure and temperatures;

    c) total heat load for heat exchangers, if required;

    d) utility requirements including electrical, water, air, and steam;

    e) pipe, valve, and orifice sizes;

    f) instrumentation, safety devices, control schemes, and wiring diagrams;

    g) filtration requirements;

    h) height of overhead tank above centerline of machine.

11) Seal system arrangement drawing and list of connections.

12) Seal system components drawing and data, including the following:

    a) pumps and drivers;

    b) heat exchangers, filter, and reservoirs;

    c) instrumentation.

13) Seal assembly drawing and part numbers.

14) Electrical and instrumentation arrangement drawing and list of connections:

    a) vibration warning and shutdown limits;

    b) bearing temperature warning and shutdown limits;

    c) lube-oil temperature warning and shutdown limits;

    d) lube-oil pressure warning and shutdown limits;

    e) lube-oil level warning and shutdown limits;

    f) machine discharge pressure and temperature warning and shutdown limits;

    g) seal, pressure, temperature, flow warning, and shutdown limits.

15) Electrical and instrumentation arrangement drawing and list of connections.

16) Buffer gas system schematic and bill of material.

17) Buffer gas system arrangement drawing and list of connections.

18) Buffer gas system component drawings and data, including the following:

    a) control devices;

    b) pressure and filtration requirements.

19) Datasheets provided with proposal as-built.

20) Supplier shall furnish the allowable forces and moments for each nozzle in tabular form with the proposal.

21) The supplier shall provide documentation showing the gear has met the quality levels of ANSI/AGMA ISO 1328-1-B14 Grade 4.

22) The supplier shall make available to the purchaser the results of the gear tooth contact check for each gear set installed in the job gear box.

23) Certificates for gearing materials:

    a) mill test reports for all gear element components;

    b) ultrasonic testing of all gear element components after rough machining;

    c) record of all heat treatment and resulting hardness vs case depth of all welds on rotating elements;

    d) magnetic particle inspection of gear and pinion teeth;

    e) results of quality control checks;

    f) gear tooth surface finish;

    g) plating of teeth;

    h) tooth profile, helix deviation pitch error, and cumulative pitch error;

    i) contact checks in job casing;

    j) records of all radiographs and ultrasonic testing;

    k) hardness vs case depth.

24) Predicted noise level, sound pressure, and sound power level.

25) Metallurgy of major components identified with ASTM, AISI, ASME, or SAE numbers stated in proposal.

26) Lateral analysis report when specified shall also include a stability analysis.

27) Torsional analysis report.

28) Vibration analysis conducted on machines that require disassembly after balancing to allow machine assembly. The supplier shall also provide historical unbalance data for the machine size and type.

29) Performance data and curves, sufficient performance data to enable the purchaser to properly design a control system and surge prevention.

30) Dimensions taken from each impeller before and after overspeed testing shall be submitted for review.

31) Mechanical running test report to include the following:

    a) unfiltered vibration;

    b) plots showing synchronous vibration and phase angle, filtered and unfiltered;

    c) when specified, data shall be furnished in polar form;

    d) when specified, tape recordings shall be made of all real time vibration data;

    e) electrical and mechanical runout at each probe.

    Immediately upon completion of each witnessed mechanical or performance test, copies of the log and data recorded during the test shall be given to the witnesses.

32) Coupling selection and rating.

33) List of spare parts recommended for start-up and normal maintenance purposes.

34) List of the special tools furnished for maintenance.

35) The supplier shall provide the purchaser with instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

36) A description of any special weather protection required for start-up, operation, and period of idleness under the site conditions specified on the datasheets.

37) A complete list of utility requirements: quantity, filtration, and supply pressure of the following:

    a) steam;

    b) water;

    c) electricity;

    d) air;

    e) gas;

    f) lube oil and seal oil (quantity and supply pressure);

    g) heat loads;

    h) power ratings and operating power requirements for auxiliary drivers.

38) A list of machines similar to the proposed machines that have been installed and operating under conditions analogous to those specified in the inquiry.

39) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment, including any unacceptable speeds due to natural frequencies.

40) A list of any components that can be construed as being of alternative design, requiring purchaser's acceptance.

41) A summary of the materials of construction for the compressor, including hardness for materials exposed to H_2S.

42) The maximum seal gas rates (injection or eduction) and rated or expected inner seal-oil leakage rates, if applicable.

    a) When self-acting dry gas seals are supplied, expected seal gas consumption, minimum seal gas supply flow and primary vent flow should be given at maximum sealing pressure and at conditions over the operating envelope of the machine.

43) If heat exchangers are furnished, the supplier shall provide the following:

    a) drawing showing cooling system details;

    b) data for purchaser heat and material balances;

    c) details of provisions for separating and withdrawing condensate;

    d) supplier's recommendations regarding provision for support and piping expansion.

44) Drawings, details, and descriptions of the operations of instrumentation and controls as well as the makes, materials, and type of auxiliary equipment. The supplier shall also include a complete description of the alarm and shutdown facilities to be provided.

45) The minimum length of straight pipe required for proper flow characteristics at the inlet and at any side inlet connection.

46) Maximum and minimum allowable seal pressure for each compressor.

47) A statement of the manufacturer's capability regarding testing (including performance testing) of the compressor and any other specified items on the train. Details of each optional test specified shall be included.

48) Performance curves shall be submitted for each section (between purchaser's process nozzles) of each casing as well as an overall curve for the train. All curves submitted prior to complete performance testing shall be marked "predicted."

    a) Any set of curves resulting from a test shall be marked "tested."

    b) If a performance test is specified, the supplier shall provide test data and curves when the test has been completed. The surge points shall be shown on the performance curves.

49) For compressors that have a back-to-back impeller arrangement, the supplier shall furnish a curve showing the expected loading on the active or inactive side of the thrust bearing vs any combination of differential pressures across the low-pressure and high-pressure sections of the casing.

50) The supplier shall provide production and delivery schedules.

51) The supplier shall submit detailed procedures, including acceptance criteria for the mechanical running test and all optional test, at least 6 weeks before the first running test.

52) The supplier shall submit progress reports.

53) All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of final certified drawings.

54) A manual containing all required operating and maintenance instructions shall be supplied not later than 2 weeks after all specified test shall have been successfully completed.

55) The supplier shall provide a “technical data manual within 30 days of completion” of shop testing, including the following:

   a) necessary certification of materials;

   b) purchase specification for all items on the bill of materials;

   c) test data to verify requirements of specifications have been met;

   d) heat treat records;

   e) results of quality test and inspections;

   f) mechanical running test data log;

   g) final assembly maintenance and running clearances;

   The supplier is also required to keep these data available for examination by the purchaser upon request, for at least 5 years.

Annex C
(informative)

Nomenclature

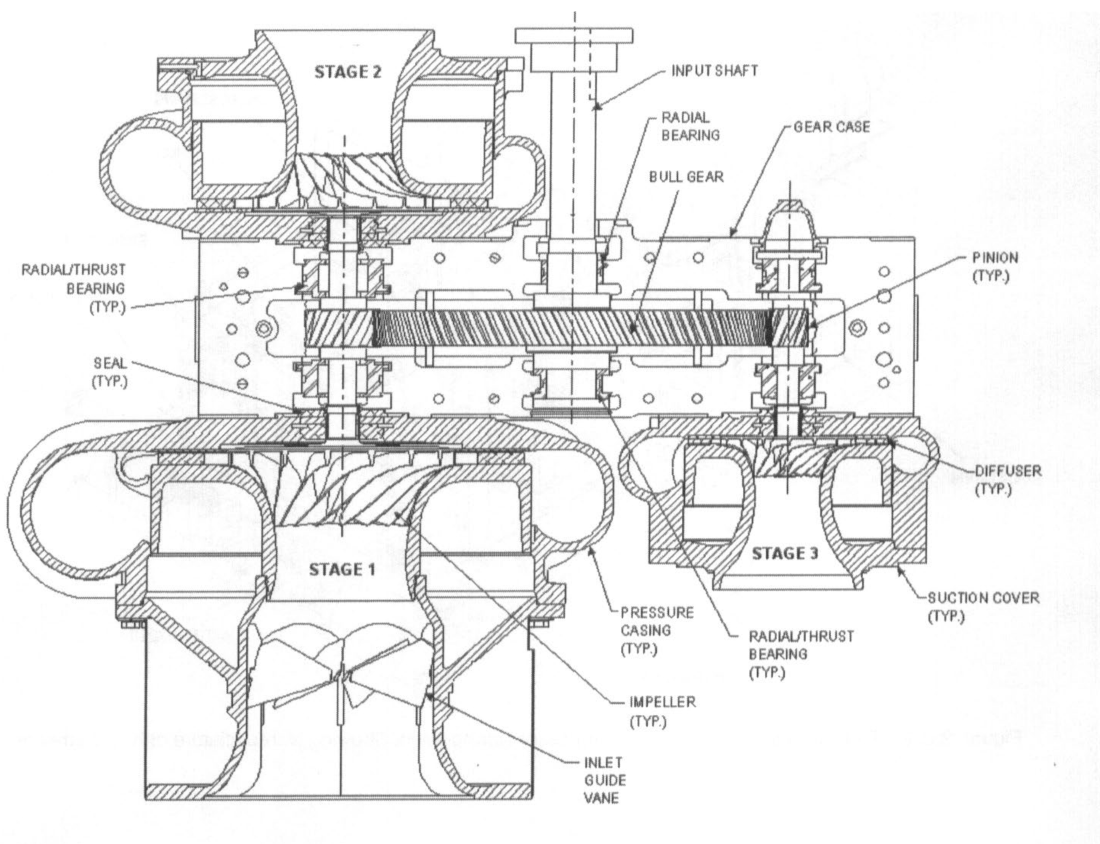


Figure C.1—Cross-sectional View Three-stage, Two-pinion Compressor

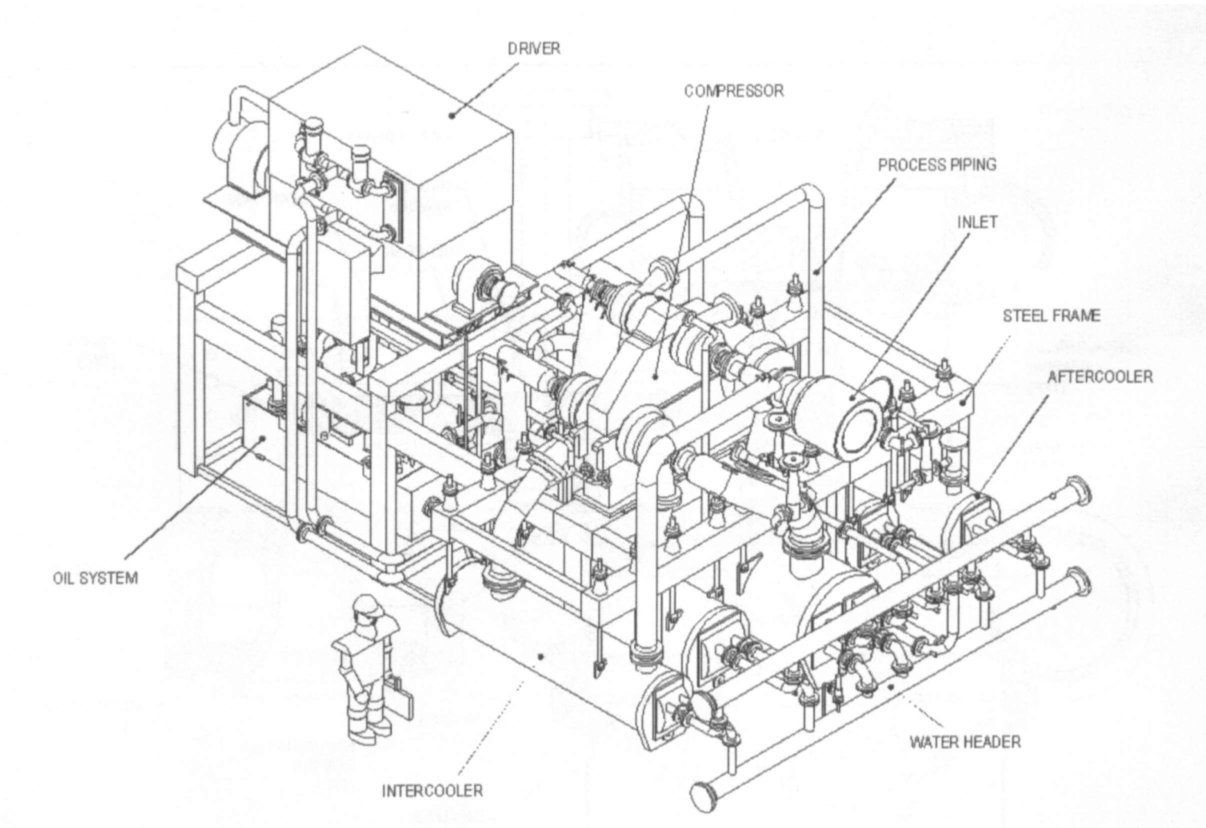


Figure C.2—Typical Integrally Geared Compressor Package

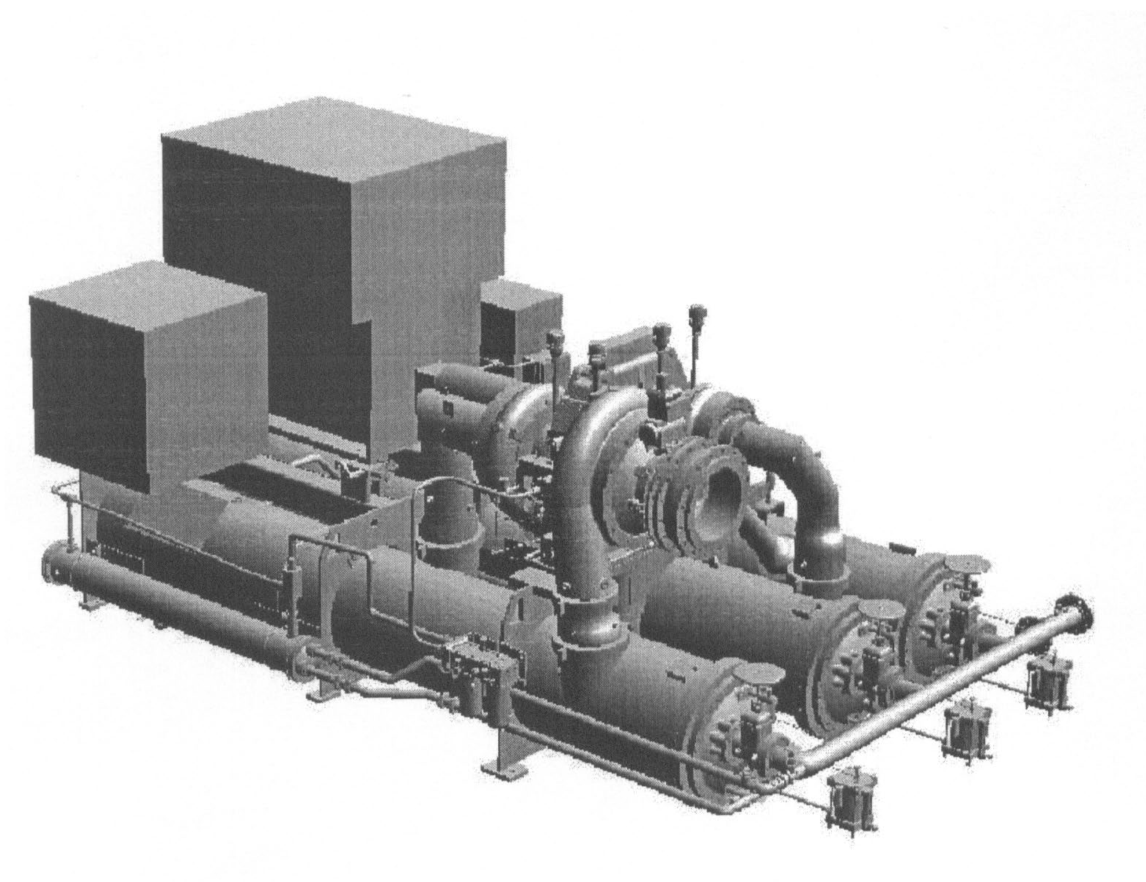


Figure C.3—Typical Integrally Geared Compressor Arrangement

Annex D
(informative)

Inspector's Checklist

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
6.2 MATERIALS					
Coating applied prior to acceptance balance	6.2.2.1	1			
PMI	6.2.3.1	1			
Impact testing	6.2.4.3	1			
Castings—material specification compliance	6.2.5.1	1			
Castings—purchaser approval of repairs	6.2.5.5.4	1			
Castings—ductile (nodular) iron	6.2.5.7	1			
Forgings—repairs	6.2.6.2	1			
Welding—nonpressure components	6.2.7.1	1			
Welding—pressure-containing and rotating parts	6.2.7.2	1			
6.3 CASINGS					
Jackscrews, dowels, and special tools	6.3.1.5	1			
Depth of threaded holes	6.3.1.6.2	1			
Studs instead of cap screws	6.3.1.8.3	1			
Socket-head or spanner-type bolting	6.3.2.5	3			
Adequate clearance at bolts	6.3.1.8.4	1			
Bolting materials	6.3.1.8.8	1			
Welding	6.3.1.9	1			
Casing repair—minimum level of inspection and purchaser review	6.3.2.1	1			
Casing repair—major repairs	6.3.2.4.1	1			
Casing repair—material standards	6.3.2.5	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Pressure casings—plate edges	6.3.2.6.1	1			
Pressure casings—MPT or LPT	6.3.2.6.2	1			
Pressure casings—weld QC	6.3.2.6.3	1			
Pressure casings—full penetration welds	6.3.2.6.4	1			
Casings—heat treatment	6.3.2.6.5	1			
Pressure-containing weld inspection	6.3.2.6.6	1			
Materials inspection standards	6.3.3.3	1			
Cast steel casings—acceptability of defects	6.3.3.4	1			
Pressure casing connection size	6.4.1.4	1			
Casing connections—welding before hydro test	6.4.1.7	1			
Main process connection orientation	6.4.2.1	1			
Flanges	6.4.2.2	1			
Cast iron flanges	6.4.2.9	1			
Concentricity of bolt circle and bore	6.4.2.13	1			
Steel flange facing finish	6.4.2.14	1			
Machined and studded connections	6.4.2.15	1			
Flanges parallel within 0.5 degrees	6.4.2.17	1			
Auxiliary connections—minimum size	6.4.3.3	3			
Auxiliary connections—threaded	6.4.3.4	3			
Auxiliary connections—flanges	6.4.3.2	1			
Auxiliary connections—allowable types	6.4.3.3	1			
Auxiliary connections—pipe nipples	6.4.3.6	1			
Auxiliary connections—socket weld gap	6.4.3.7	1			
Auxiliary connections—lube or seal service	6.4.3.4	1			
Threaded openings for tapered pipe threads	6.4.4.1	1			
Tapered pipe threads	6.4.4.2	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Seal welding tapered pipe threads	6.4.4.3	1			
Pipe nipples for threaded openings	6.4.4.4	1			
Plugs for threaded openings	6.4.4.5	1			
Machine mounting surfaces	6.5.1	1			
6.6 ROTATING ELEMENTS					
Shaft ends for couplings	6.6.1.1	1			
Impeller and shaft marking	6.6.1.1	3			
Shaft sensing areas for probes	6.6.1.2	1			
Shaft sensing areas—final surface finish	6.6.1.3	1			
Thrust collar surface finish and TIR	6.6.1.6	1			
Fabricated impeller inspection	6.6.2.3	1			
Cast impeller inspection	6.6.2.4	1			
Cast impeller repair	6.6.2.5	1			
Welding not permitted for impeller balancing	6.6.2.6	1			
MPT or LPT of impellers after overspeed	6.6.2.7	1			
6.8 DYNAMICS					
Confirmation of critical speeds	6.8.3.1.9	1			
Unbalanced rotor response verification test	6.8.3	1			
Additional testing	6.8.3.2	1			
Rotating element—component balance	6.8.7.1	1			
Rotating element—sequential multiplane balance	6.8.7.6	1			
Rotating element—if disassembled after balance	6.8.7.7	1			
Rotating element—reassembly check balance	6.8.7.7	1			
Operating speed balance	6.8.7.8	1			
Operating speed balance procedure	6.8.8	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
6.9.2 INTEGRAL GEARING					
Doweled or keyed gearbox	6.9.2.1	3			
Inspection cover	6.9.2.7	3			
Documentation for gearing quality level	6.9.4.4.5	3			
Tooth surface finish	6.9.4.4.14	3			
6.9.5 NAMEPLATES AND ROTATION ARROWS					
Nameplate at readily visible location	6.9.3.1	1			
Nameplate material	6.9.3.2	1			
Nameplate contents	6.9.5.2	3			
Rotation arrows	6.9.5.3	3			
Lateral critical speeds on nameplate	6.9.3.6	1			
7.3.1 BASEPLATES AND SOLEPLATES					
Jackscrews	7.2.1.2.1	1			
Alignment shims	7.2.1.2.2	1			
Machinery mounting surfaces	7.2.1.2.3	1			
Anchor bolt clearance	7.2.1.2.8	1			
Vertical levelling screws	7.2.1.2.9	1			
Radiused corners for grout	7.2.1.2.10	1			
Hold-down bolt clearance	7.2.1.2.13	1			
Wrench clearance	7.2.1.2.13	1			
Grout contacting surface preparation	7.2.1.2.16	1			
Mounting surface preservation	7.2.1.2.18	1			
Seal welded joints	7.2.2.3	1			
Levelling pads or targets	7.2.2.8	1			
Additional pads or targets	7.2.2.8.2	1			
Lifting lugs	7.2.2.9.1	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Grout fill and vent holes	7.2.2.10.1	1			
Soleplates supplied	7.3.2.3	3			
Soleplate thickness	7.2.3.2	1			
Soleplate size	7.2.3.3	1			
Soleplates fully machined	7.2.3.5	1			
Subsoleplates	7.2.3.6	1			
7.4 CONTROLS AND INSTRUMENTATION					
Controls ingress protection level	7.3.1.4	1			
Terminal box ingress protection level	7.3.1.5	1			
Conduit and cable location and installation	7.3.1.6	1			
Transducers per API 670	7.4.7.5	3			
Monitors per API 670	7.4.7.6	3			
Bearing temperature sensors per API 670	7.4.7.8	3			
Bearing temperature monitor per API 670	7.4.7.9	3			
Accelerometer per API 670	7.4.7.10	3			
Accelerometer monitor per API 670	7.4.7.11	3			
7.5 SPECIAL TOOLS					
Use of tools	7.4.3	1			
Tool packing and marking	7.4.4	1			
7.9.1 PIPING AND APPURTENANCES					
Breakout spools	7.8.1.1.3	1			
Provisions to bypass bearings	7.8.1.1.4	1			
Provisions to bypass dry gas seals	7.8.1.1.5	1			
Instrument piping	7.8.1.2	1			
Process piping	7.8.1.3	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
8.1 INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT—GENERAL					
Access to vendor's quality control program	8.1.8	1			
8.2 INSPECTION					
Painting before hydro test	8.2.1.2	1			
Cleanliness	8.2.1.5	1			
Hardness of parts, welds, and heat-affected zones	8.2.1.7	1			
Radiographic inspection	8.2.3	1			
Ultrasonic inspection	8.2.4	1			
Magnetic particle inspection	8.2.5	1			
Liquid penetrant inspection	8.2.6	1			
Gear contact checks	8.2.2	3			
8.3 TESTING					
Contract shaft seals and bearings used	8.3.2.1.1	3			
Oil system cleanliness before testing	8.3.2.1.5	3			
Joint and connection tightness	8.3.5.6 8.3.3.2.1	1 3			
Warning, protective, and control devices	8.3.5.7 8.3.2.3.1	1 3			
Hydrostatic test—pressure	8.3.2.1	1			
Hydrostatic test—duration	8.3.2.3	1			
Hydrostatic test—chloride content	8.3.2.4	1			
Impeller overspeed test	8.3.3	1			
Residual magnetism	8.3.5	1			
Dry gas seals	8.3.4	1			
Mechanical running test—operation of equipment and test instrumentation	8.3.5.10.1 8.3.2.3.1	1 3			
Mechanical running test—unfiltered vibration	8.3.5.10.2	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Mechanical running test—casing vibration	8.3.2.3.3	3			
Mechanical running test—vibration plots	8.3.5.10.3	1			
Mechanical running test—real-time vibration data recorded	8.3.5.10.5 8.3.2.3.6	1 3			
Mechanical running test—seal flow data	8.3.5.10.6	1			
Mechanical running test—lube oil and seal oil variations	8.3.5.10.7	1			
Mechanical running test—hydrodynamic bearing inspection	8.3.5.11.1	1			
Mechanical running test—shaft end seal inspection	8.3.5.12	1			
Mechanical running test—tooth mesh inspection	8.3.2.4.1	3			
Mechanical running test—spare rotor	8.3.2.4.3	3			
Gas test after hydro test	8.3.7.3	1			
Assembled compressor gas leak test—seal pressure	8.3.3.2	3			
Assembled compressor gas leak test—max discharge pressure	8.3.3.3	3			
Sound-level test	8.3.7.4	1			
Auxiliary-equipment test	8.3.7.5	1			
Post-test inspection of internals	8.3.7.6	1			
Full-load/full-pressure/full-speed test	8.3.7.7	1			
Post-test inspection of coupling fit	8.3.7.8	1			
Spare-parts test	8.3.7.9	1			
8.4 PREPARATION FOR SHIPMENT					
Preparation for shipment	8.4.1	1			
Testing completed and equipment released	8.4.3	1			
Coating on exterior surfaces	8.4.3.1.1	1			
Exterior machined surfaces coating	8.4.3.2	1			

Item (Inspector's Checklist Part 3)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Interior of equipment	8.4.3.3	1			
Internal surfaces of bearing housings	8.4.3.5	1			
Flange covers	8.4.3.6	1			
Threaded openings	8.4.3.7	1			
Bevelled welding openings	8.4.3.8	1			
Lifting point identification	8.4.3.9	1			
Equipment tagging and packing lists	8.4.3.11	1			
Spare rotor storage preparation	8.4.3.12	1			
Spare rotor container	8.4.3.12.3	1			
Cradle support liner	8.4.3.13	1			
Rotor preparation for vertical storage	8.4.3.12.4	1			
Fit-up and assembly of piping and heat exchangers	8.4.3.14	1			
Shaft and coupling protection	8.4.3.15	1			
Auxiliary connection marking	8.4.4	1			
Auxiliary piping match marks	8.4.6	1			
IOM shipped with equipment	8.4.7	1			
Wood used in export shipping	8.4.8	1			

Annex E
(informative)

External Forces and Moments

For integrally geared compressors, it is not possible to give a formula to calculate the maximum allowable piping forces and moments on each casing flange. The limiting criteria are the gear contact pattern, the impeller/stator gap, and the alignment of the dry gas seals. Alignment of the dry gas seals shall be established and agreed upon by the dry gas seal supplier and compressor supplier. The maximum value of the external forces and moments, which leads to acceptable deformations and therefore acceptable changes of the gear contact pattern and the impeller/stator gap, depends on various parameters. These parameters include:

a) volute geometry;

b) volute wall thickness;

c) length of overhang;

d) gear case geometry;

e) gear case wall thickness.

The possible combinations are nearly endless and unique for each manufacturer's design. Each manufacturer has limits based on his/her experience for each volute size and gear case combination for a given specific machine. The values are available from the manufacturer with the quotation. Allowable nozzle loads on integrally geared compressors are much less than beam or overhung compressors covered in Part 2. It is a common practice on integrally geared compressors to require expansion joints in order to minimize the piping loads on the machine flanges and to ensure that piping loads are within the allowable limits for the particular unit. If expansion joints are not to be allowed or if they are very preferably to be avoided if at all possible, it is necessary to obtain values for allowable nozzle loading very early, preferably in the quotation stage. This facilitates the piping discipline to allow for a carefully designed piping system that will meet the manufacturer's allowable nozzle loading criteria.

See 6.5.2 of Part 3 and Annex B; allowable nozzle loading on main process nozzles that are customer connections should be supplied with the quotation. In the event these values are not furnished, they should be a minimum of the values in NEMA SM 23. Where not supplied, NEMA SM 23 values can therefore be used to develop the piping design.

NOTE Where a supplier has furnished allowable nozzle loadings, they can be less than allowed by NEMA SM 23.

Annex F
(normative)

Rating Formulae for Integral Gearing

F.1 Rating Formulae for Integrally Geared Compressor

The rating formulae given below are based on the methods from AGMA 2101-D04. The constant of 0.8 at the beginning of the formulae below is to provide increased reliability.

F.2 Pitting Resistance Power Rating

The pitting resistance allowable transmitted power (kw), P_{az}, for a gear set is:

$$P_{\mathrm{az}} = 0.8\left(\frac{\omega_1 b}{1.91\times10^7}\right)\left(\frac{Z_{\mathrm{I}}}{K_{\mathrm{v}}K_{\mathrm{H}}C_{\mathrm{SF}}}\right)\left(\frac{d_{\mathrm{w1}}\sigma_{\mathrm{HP}}Z_{\mathrm{N}}}{Z_{\mathrm{E}}}\right)^2 \quad \text{(F.1)}$$

where

ω_1 is the pinion speed (rpm);

σ_{HP} is the allowable contact stress number (see F.7) (N/mm^2);

b is the face width (mm);

d_{w1} is the operating pitch diameter of pinion (mm) = $2a/(u + 1)$;

a is the operating center distance (mm);

u is the gear tooth ratio (never less than 1.0);

C_{SF} is the API 617 service factor;

K_{v} is the dynamic factor (see F.5);

K_{H} is the load distribution factor (see F.4);

Z_{E} is the elastic coefficient = 190 [N/mm^2]$^{0.5}$ for steel pinion and gear;

Z_{I} is the geometry factor (reference AGMA 908);

Z_{N} is the stress cycle factor for pitting resistance (see F.6).

F.3 Bending Strength Power Rating

The bending strength allowable transmitted power (kw), P_{ay}, for a gear pair is:

$$P_{ay} = 0.8\left(\frac{\omega_1 d_{w1}}{1.91 \times 10^7}\right)\left(\frac{b m_t Y_J \sigma_{FP} Y_N}{K_V K_H K_{SF}}\right) \tag{F.2}$$

where

m_t is the transverse module (equal to normal module divided by the cosine of the helix angle at the standard pitch diameter);

Y_J is the geometry factor (reference AGMA 908);

K_{SF} is the API 617 SF;

σ_{FP} is the allowable bending stress number (see F.7) (N/mm^2);

Y_N is the stress cycle factor for bending (see F.6).

F.4 Load Distribution Factor, K_H

If the value of K_H calculated below is less than 1.1, then 1.1 shall be used as the value of K_H. Gear designs shall not result in a calculated value of K_H over 1.50 without approval from the purchaser.

$$K_H = 1.0 + 0.8\left(K_{Hpf} + 0.054 + 0.4032 \times 10^{-3} b - 1.152 \times 10^{-7} b^2\right) \tag{F.3}$$

where

b is the face width of narrower member of gear set (mm);

K_{Hpf} = bod – 0.025 when $b \leq 25$ mm,

= bod – 0.0375 + 0.000492b when $25 < b \leq 432$,

= bod – 0.1109 + 0.000815b – 3.53 $\times 10^{-7} b^2$ when $432 < b \leq 1020$;

bod = the greater of 0.05 or $b/(10d_{w1})$.

The distance from the center of the gear mesh to the center of the bearing span divided by the bearing span should be less than 0.175. Leads should be properly modified by crowning or lead correction.

The tooth contact should be checked at assembly, with contact adjustments as required.

If these conditions are not met, or for wide face gears, an analytical approach can be used to determine a more conservative load distribution factor, with prior approval by the purchaser.

F.5 Dynamic Factor, K_v

ANSI/AGMA ISO 1328-1-B14 Grade 5 = > K_v = 1.150

ANSI/AGMA ISO 1328-1-B14 Grade 4 = > K_v = 1.130

ANSI/AGMA ISO 1328-1-B14 Grade 3 = > K_v = 1.110

ANSI/AGMA ISO 1328-1-B14 Grade 2 = > K_v = 1.090

The dynamic factor, K_v, does not account for dynamic tooth loads that can occur due to torsional or lateral natural frequencies. System designs should avoid having such natural frequencies close to an excitation frequency associated with an operating speed since the resulting gear tooth dynamic loads can be very high.

F.6 Stress Cycle Factors, Z_N and Y_N

Z_N $= 2.466N^{-0.056}$, for $N \leq 10^{10}$,

$= 0.68$, for $N > 10^{10}$, pitting resistance stress cycle (life) factor;

Y_N $= 1.6831N^{-0.0323}$, bending strength stress cycle (life) factor;

N is the number of stress cycles;

N = pinion rpm × 1.052 × 10^7 for the pinion;

N = gear rpm × 1.052 × 10^7 × number of pinions in mesh for the bull gear.

NOTE These factors are based on the lower line in Figure 17 and Figure 18 of ANSI/AGMA 2101-D04 with 175,316 hours (20 years × 365.242 days/year × 24 hours/day) of continuous service at rated operating speed.

F.7 Allowable Stress Numbers, σ_{HP} and σ_{FP}

The values of σ_{HP} and σ_{FP} shall be for Grade 2 materials per ANSI/AGMA 2101-C95, Section 16.

F.8 Reverse Loading

For idler gears and other gears where the teeth are completely reverse loaded on every cycle, use 70 % of the allowable bending stress number, σ_{FP}, in ANSI/AGMA 2101-D04.

F.9 Service Factor, C_{SF} and K_{SF}

The service factor used for integrally geared centrifugal compressors shall be 1.4 when driven by an induction motor, 1.6 when driven by a gas or steam turbine, and 1.7 when driven by a synchronous motor or internal combustion engine.

Axial and Centrifugal Compressors and Expander-compressors
Part 4—Expander-compressors

1 Scope

This part of API 617 specifies requirements for expander-compressors, in addition to the general requirements specified in Part 1. This scope covers only radial inflow expanders and compressors on a single common shaft (expander-compressor). Annex D covers integrally geared expanders used for generator drive.

2 Normative References

Referenced documents indispensable for the application of this document are listed in Section 2 of Part 1.

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

For the purposes of this document, the terms, definitions, acronyms, abbreviations, and symbols given in Part 1 apply.

NOTE A cross section showing nomenclature of an expander-compressor can be found in Annex C.

3.1
expander efficiency
Total (stagnation) condition at the inlet flange to static condition at the exit of the discharge diffuser.

3.2
impeller
The rotating part of the compressor or expander designed to move a fluid by rotation (compressor) or cause rotation by fluid movement (expander).

NOTE Interchangeably used for both the compressor and expander wheel since they share similar requirements in this standard.

4 Dimensions and Units

The dimensional and unit requirements of Part 1 shall apply.

5 Requirements

5.1 Statutory Requirements

The statutory requirements of Part 1 shall apply.

5.2 Unit Responsibility

The unit responsibilities of Part 1 shall apply.

6 Basic Design

6.1 [●] General

6.1.1 The expander-compressor shall be identified with the primary objective as specified for the application. The primary objective of utilizing the turbo-expander is either the expander (see 6.1.2) or the compressor (see 6.1.3).

NOTE The identification of the primary objective is used to determine priority of performance objectives during design, testing, and operation.

6.1.2 Expander

NOTE For the majority of expander-compressor applications, the primary objective is achieving the best efficiency on the expander side (e.g. refrigeration applications). In these applications, the compressor acts as a "brake" to absorb the mechanical energy generated by the expander in the expansion process.

6.1.2.1 The expander shall meet at least 98 % of the predicted efficiency at the certified point (see 8.4.5.2.1).

6.1.2.2 The compressor shall meet at least 98 % of the predicted compressor efficiency at the certified point.

NOTE 1 The shaft power produced by the expander, less friction losses, is entirely transmitted to the brake compressor, and so compressor-loaded expanders achieve a power balance that determines the speed of the machine.

NOTE 2 If the expander power is more than expected, then the speed of the machine will be higher than predicted.

NOTE 3 If the compressor power is more than expected, then the speed of the machine will be lower than predicted.

6.1.2.3 When a speed increase is necessary to achieve specified performance, all design margins such as separation margins, overspeed margins, maximum continuous margins, etc. shall be maintained.

6.1.2.4 The maximum continuous speed shall be at least 105 % of the "as-tested" rated speed.

6.1.2.5 The compressor head-capacity characteristic curve at the rated speed shall rise continuously from the rated point to predicted surge.

6.1.2.6 The compressor shall be suitable for continuous operation at any capacity on the predicted performance curve(s) at least 10 % greater than the predicted surge capacity shown in the proposal.

NOTE It is common for flow to be recycled through the compressor during turndown operation.

6.1.3 Compressor

NOTE In these applications, the compressor is the primary objective. The expander is treated as a variable speed driver for the compressor.

6.1.3.1 The compressor shall be in accordance with Part 2.

6.1.3.2 The expander driver shall be in accordance with 7.6 of Part 1.

6.2 Materials

6.2.1 Materials shall be in accordance with 6.2 of Part 1. Refer to Annex F of Part 1 for a table of typical materials.

6.2.2 If traces of mercury have been specified, aluminum impellers shall be treated by hard anodizing or other approved methods.

6.3 Casings

6.3.1 General

Casings shall be in accordance with 6.3 of Part 1 and the additional requirements as follows.

6.3.2 Pressure-containing Casings

6.3.2.1 [●] The maximum allowable working pressure (MAWP) of the casing(s) shall be at least equal to the relief valve set pressure(s) specified by the purchaser.

6.3.2.1.1 If a relief valve set pressure is not specified, the MAWP of an expander casing shall be at least 1.1 times the maximum specified inlet pressure (gauge).

6.3.2.1.2 Overpressure protection shall be furnished by the purchaser.

6.3.2.1.3 If a relief valve set pressure is not specified, the MAWP of the compressor casing of an expander-compressor shall be at least 1.25 times the maximum specified discharge pressure (gauge).

6.3.2.1.4 Overpressure protection shall be furnished by the purchaser.

6.3.2.1.5 When the purchaser has not supplied a relief valve setting, the purchaser shall be responsible for ensuring that casing pressure will not exceed casing MAWP ratings as set by 6.3.2.1.1 and 6.3.2.1.2.

6.3.2.2 O-rings, gaskets, or other sealing devices that may be used on radially spilt casings shall be confined in machined grooves and shall be made of materials suitable for all specified service conditions.

6.3.2.3 Provisions for lifting the casings and removing the center section shall be provided.

6.3.2.4 The expander-compressor casing shall be designed to contain parts that might separate in the event of uncontrolled overspeed.

6.3.3 Casing Repairs

Casing repairs shall be in accordance with 6.3.2 of Part 1.

6.3.4 Material Inspection of Pressure-containing Parts

Material inspection of pressure-containing parts shall be in accordance with 6.3.3 of Part 1.

6.4 Pressure Casing Connections

6.4.1 General

In addition to the requirements of 6.4 of Part 1, the following sections in 6.4 shall apply.

6.4.2 Main Process Connections

Main process connections shall be in accordance with 6.4.2 of Part 1.

6.4.3 Auxiliary Connections

Auxiliary connections shall be in accordance with 6.4.3 of Part 1 and at least DN 15 (NPS $^1/_2$).

6.5 Stationary Components

6.5.1 Casing Support Structures

NOTE 1 Expander-compressors have no coupling; therefore, there are no special requirements for casing support structures.

NOTE 2 Expander-compressor units do not require highly finished mounting surfaces.

6.5.2 External Forces and Moments

6.5.2.1 Expander-compressor packages shall be designed to withstand external forces and moments on each nozzle calculated in accordance with Equation (F.1) and Equation (F.2) of Annex F.

6.5.2.2 The vendor shall furnish the allowable forces and moments for each nozzle in tabular form.

6.5.3 Variable Nozzles and Heat Shields

6.5.3.1 Each expander shall be equipped with variable nozzles (variable inlet guide vanes).

NOTE Variable nozzles permit the efficient conversion of head into velocity throughout the design range of the unit.

6.5.3.2 Variable nozzles shall be sized capable of flowing at least 110 % of the mass flow at any specified operating condition.

6.5.3.3 Actuating devices shall be capable of operation at all specified operating conditions, including maximum inlet pressure, maximum flow, and minimum discharge pressure.

6.5.3.4 Variable nozzles and actuators shall be capable of closing with maximum inlet pressure at all flow conditions.

NOTE Variable nozzles are not shutoff devices and are not intended to replace the expander inlet trip valve.

6.5.3.5 Actuators shall be equipped with an agreed force limiting device to ensure no over forcing in closing or opening the inlet guide vanes.

6.5.3.6 If variable nozzles are used for toxic, flammable, or explosive process gas, the linkage passing through the casing or enclosure shall be sealed.

6.5.3.7 If required, an insulating heat shield shall be provided between the cold expander process fluids and the bearing cavity.

NOTE See Annex F of Part 1 for typical heat shield materials.

6.6 Rotating Elements

6.6.1 General

6.6.1.1 Rotating elements shall be in accordance with 6.6 and D.4.7 of Part 1 and this section.

6.6.1.2 Each impeller and shaft shall be clearly marked with a unique identification number in an accessible area that is not prone to maintenance damage.

6.6.2 Shaft Sleeve

6.6.2.1 Unless other shaft protection is approved by the purchaser, replaceable components shall be furnished at labyrinth shaft seal locations.

6.6.2.2 Sleeves, spacers, or bushings shall be made of materials that are corrosion-resistant in the specified service.

6.6.3 Shafts

For precipitation-hardened stainless steel shafts, the vendor shall provide a coating or overlay on the journals to prevent wire wooling.

NOTE 1 Chrome plating, weld overlay, high-velocity oxygen fuel, high-velocity liquid fuel, and graphite impregnation are some of the methods that have been used successfully to prevent wire wooling.

NOTE 2 It is not applicable to magnetic bearings as there is no actual contact between the journals and the magnetic bearings.

6.6.4 Impellers

For impeller requirements, see 6.6.2 of Part 1.

6.6.5 Thrust Balancing

6.6.5.1 A balance cavity, line, and porting can be provided if required to limit axial loads on the thrust bearings.

6.6.5.2 If an automatic or fixed thrust equalizing valve is provided (see 6.7.3.3), this valve shall be flanged and sized to handle balance drum gas leakage at twice the initial design labyrinth clearance without exceeding the load rating of the thrust bearings.

NOTE For magnetic bearings, refer to D.4.9.3.1 of Part 1.

6.6.5.3 If an automatic thrust equalizing valve is required (see 6.7.3.3) to limit thrust load, this valve shall react to changes in thrust load to actively maintain a low thrust load on the thrust bearings by injecting to or venting from balancing chambers inside the machine.

6.7 Bearings and Bearing Housings

6.7.1 General

6.7.1.1 Unless otherwise specified, hydrodynamic radial and thrust bearings shall be provided.

NOTE The typical expander-compressor has both the radial and thrust bearing built into a single assembly.

6.7.1.2 [●] If specified, magnetic bearings shall be supplied in accordance with D.4.9 of Part 1.

6.7.1.3 Bearing material selection criteria shall include compatibility with the process gas.

6.7.2 Hydrodynamic Radial Bearings

6.7.2.1 Sleeve or pad type bearings shall be used.

6.7.2.2 Unless otherwise specified, hydrodynamic radial bearings shall be fitted with bearing metal temperature sensors installed in accordance with API 670.

6.7.3 Hydrodynamic Thrust Bearings

6.7.3.1 Hydrodynamic thrust bearings shall comply with the requirements of 6.7.3 of Part 1 and the following requirements in this section.

6.7.3.2 Hydrodynamic thrust bearings shall be fix geometry or tilt pad design.

6.7.3.3 Thrust bearings shall be designed for equal thrust capacity in both axial directions.

6.7.4 Bearing Housings

6.7.4.1 Bearing housings shall be in accordance with 6.7.4 of Part 1 and the following requirements in this section.

6.7.4.2 Rotor support system parts (bearings, bearing housings, bearing shells, and bearing brackets) shall be separable from the mating casings.

6.7.5 Magnetic Bearings

6.7.5.1 [●] The purchaser will specify any agent (including trace quantities) present in the process gas and seal/cooling gas streams including constituents that may cause hazardous conditions and failure of magnetic bearing components.

NOTE 1 Typical agents of concern are hydrogen sulphide, humidity, CO_2, Hg, salty monoethylene glycol, tetraethylene glycol, and acetylene.

NOTE 2 Presence and concentration of these agents and constituents during normal operation, transient conditions, and maintenance activities (e.g. liquid injection) are equally of concern.

6.7.5.2 The design of seal gas system shall ensure that the bearing housing be free from any liquid or condensate, unless the active magnetic bearing (AMB) system is specifically designed for such conditions.

NOTE Some AMB systems can be designed to allow for some degree of liquid exposure.

6.7.5.3 The proposal shall provide alternatives to mitigate the risk of hazardous conditions and failure of magnetic bearing components for any incompatible agent present in the process gas and seal/cooling gas streams.

6.8 Dynamics

6.8.1 General

Dynamics shall be in accordance with 6.8 and D.4.8 of Part 1.

6.8.2 Vibration Balancing

6.8.2.1 The balancing method described in 6.8.2.2 through 6.8.2.5 shall apply only to single-shaft expander-compressors that require rotor disassembly and reassembly to install.

NOTE Expander-compressors in cryogenic service are typically single-shaft rotors that require disassembly and reassembly of the rotor to install in the machine casing. By requiring index balancing, either the compressor or expander component can be replaced individually without requiring the complete rotor to be rebalanced.

6.8.2.2 The expander wheel, compressor wheel, and the shaft shall be balanced using an index balancing procedure.

6.8.2.2.1 All machining of components shall be completed before balancing.

6.8.2.2.2 The wheels shall be supported by a concentric arbor during the balancing procedure.

6.8.2.2.3 Two-plane balancing is preferred, but single-plane balancing may be used for components with a length to diameter (L/D) ratio of 0.2 or less.

6.8.2.2.4 Each component shall be balanced so that the level of residual unbalance for each balance plane does not exceed the greatest value determined by Equation (3) as applicable from Part 1.

NOTE For information on the index balance procedure, refer to API 684.

6.8.2.3 Prior to starting the index balancing procedure for the compressor and expander wheels, the following steps shall be performed to check the integrity of the fits between the wheels and arbor.

a) Mount the wheel at an arbitrary 0° location on the arbor. Record the unbalance reading of the assembly.

b) Dismount and remount the wheel on the arbor in the original 0° position. Record the unbalance.

c) The vector reading from item b) shall be within 20 % of the vector reading from item a). If not, the arbor fit shall be checked for poor contact, dirt, or other items affecting the fit integrity.

6.8.2.4 Index balance both wheels, using an arbor, to the tolerance specified in 6.8.2.2.

NOTE After this step, the wheels should be in balance and no further corrections should be required.

6.8.2.5 The shaft index balance procedure shall be performed using both wheels mounted in the following manner.

a) Mount the expander and compressor wheels on the shaft. Both wheels should be marked to an arbitrary 0° location on the shaft.

b) Identify appropriate balance planes on the shaft. Perform index balancing of the shaft using the wheels to the tolerance specified in 6.8.2.2.

c) Both wheels shall be treated as one part and turned together during the index balancing procedure.

6.8.2.6 [●] If specified, rotors shall be assembled and the balance verified.

6.8.2.6.1 The residual unbalance for the randomly assembled components shall not exceed 10 times the maximum allowable residual unbalance as determined by Equation (3) as applicable in Part 1.

6.8.2.6.2 Assembled rotors that fail to meet these criteria shall be balance corrected by repeating the component index balance, not by trim balancing the assembly.

6.8.2.7 Residual Unbalance Procedure

6.8.2.7.1 [●] If specified, a residual unbalance check shall be performed on assembled rotors.

6.8.2.7.2 The residual unbalance check shall be performed after assembly balancing or assembly check-balancing is complete and before the assembled rotor is removed from the balancing machine.

NOTE Refer to Annex A of Part 1 for a description of the procedure for residual unbalance determination.

6.9 Other Standard Specific Components

6.9.1 Expander-compressor Shaft Seals

6.9.1.1 Shaft seals shall comply with the requirement of 6.9.1 of Part 1 and the following in this section.

NOTE Expander-compressors do not have shaft end seals, but the same types of seals are used for internal sealing between the process gas and the bearing housing.

6.9.1.2 Shaft seals shall be provided to restrict the leakage of process gas into the bearing housing over the range of specified operating conditions, including start-up and shutdown.

6.9.1.3 Seals shall be suitable for specified variations in seal operating conditions that may prevail during start-up, shutdown, or settle out and during any other special operation specified.

6.9.1.4 Shaft seals used in expander-compressors may be either clearance seals or self-acting dry gas seals.

NOTE See 6.9.1 of Part 1 for information on shaft end seals.

6.9.2 Nameplates and Rotation Arrows

6.9.2.1 Nameplates and rotation arrows shall be in accordance with 6.9.3 of Part 1.

NOTE Rotation arrows are generally not provided for expander-compressors.

6.9.2.2 The following data shall be clearly stamped or engraved on the nameplate:

- vendor's name;
- serial number;
- size, type, and model number;
- design power;
- rated speed (rpm);
- trip speed (rpm);
- purchaser's item number or other reference;
- MAWP of each casing;
- maximum and minimum working temperature of each casing;
- hydrostatic test pressure of each casing;
- maximum continuous speed (N_{mc});
- lateral critical speeds up to and including the next critical above N_{mc}.

7 Accessories

7.1 Lubrication and Sealing Systems

7.1.1 If required, a pressurized oil system shall be furnished to supply oil at suitable pressure(s) to the machine.

7.1.2 Such systems shall be in accordance with API 614.

NOTE If oil-lubricated bearings expander/compressors for gas and chemical industries are equipped with labyrinth clearance seals, they are usually provided with a pressurized oil reservoir in order to recover seal gas leakage.

7.2 Mounting Fixtures

7.2.1 Baseplates and Soleplates

If soleplates or baseplates are supplied, they shall be in accordance with the requirements of 7.2.1 of Part 1.

NOTE Soleplates are not used with expander-compressors.

7.2.2 Baseplates

If a baseplate is required, it shall be furnished in accordance with 7.2.2 of Part 1.

7.3 Controls and Instrumentation

7.3.1 General

Controls and instrumentation shall be in accordance with 7.3 of Part 1 and the following in this section.

7.3.2 Vibration and Position Monitoring

7.3.2.1 Vibration transducers shall be supplied, installed, and calibrated in accordance with API 670.

7.3.2.2 [●] If specified, axial position probes shall be provided in accordance with API 670.

NOTE 1 Axial position or axial vibration monitoring with proximity probes is difficult and can compromise reliability as there are no readily available axial surfaces and can require intrusive modifications to the thrust bearing.

NOTE 2 Expander-compressors normally use pressure from active thrust compensation system rather than axial position probes for alarm/shutdown functions.

7.3.2.3 [●] If specified, vibration monitors shall be supplied and calibrated in accordance with API 670.

7.4 Special Tools

Special tools shall be furnished in accordance with 7.4 of Part 1.

7.5 Couplings and Guards

NOTE Expander-compressors do not have couplings and guards.

7.6 Drivers

NOTE Expander-compressor units do not have separate drivers.

7.7 Enclosures and Insulation

(Intentionally Left Blank)

7.8 Other Standard Specific Systems

7.8.1 Hydrodynamic Bearings

7.8.1.1 Hydrodynamic radial bearings shall be fitted with bearing metal temperature sensors installed in accordance with API 670.

7.8.1.2 [●] If specified, hydrodynamic thrust bearings shall be fitted with bearing metal temperature sensors installed in accordance with API 670.

7.8.1.3 [●] If specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API 670.

7.8.1.4 [●] The purchaser will specify the type of detectors required in 7.8.1.1 and 7.8.1.2.

7.8.2 [●] Magnetic Bearings

If magnetic thrust and radial bearings have been specified, they shall be fitted with bearing temperature sensors installed in accordance with D.4.9.2.2 of Part 1.

7.8.3 Overspeed Shutdown System

7.8.3.1 General

7.8.3.1.1 The vendor shall provide an overspeed shutdown system in accordance with API 670, consisting of:

a) electronic overspeed circuit [speed sensor(s) and logic device];

b) expander inlet trip valve equipped with solenoid valve(s).

7.8.3.1.2 An overspeed shutdown system based on a single circuit shall be provided.

7.8.3.1.3 [●] If specified, an overspeed shutdown system based on two-out-of-three voting logic shall be furnished.

7.8.3.2 Electronic Overspeed Detection System

7.8.3.2.1 An electronic overspeed detection system, consisting of a speed sensor(s) and logic device, shall be furnished.

7.8.3.2.2 The design of the circuit shall include the following.

a) Failure of either the sensor(s) or logic device shall initiate a shutdown.

b) All settings incorporated in the overspeed system shall be protected from unauthorized access.

c) It shall accept inputs from a frequency generator for verifying the trip speed setting.

d) It shall provide an output for a speed indicator.

7.8.3.2.3 Magnetic pickups shall be supplied for speed sensing.

7.8.3.2.4 A hole or grooved surface integral with the shaft or permanently mounted magnetic target shall be provided for speed sensing.

7.8.4 Expander Trip Valve

7.8.4.1 The vendor shall provide an expander inlet trip valve.

NOTE The expander inlet trip valve is not meant to act as an isolation device. The inclusion of a unit isolation valve upstream of the trip valve is typical of most installations.

7.8.4.2 The design of expander inlet trip valves shall include, but not be limited to, the following:

a) the ability to close within an agreed time not to exceed 1 second;

b) the valve shall be designed with a fail-safe spring-loaded actuator;

c) the torque capability of the actuator shall close the valve against the MAWP;

d) an extended bonnet to maintain the stem packing at a noncryogenic temperature;

NOTE It is the purchaser's responsibility to ensure that the trip valve internals operate free from hydrates and other solids, which can prevent valve closure. Wear and tear are important factors in the consideration of the valve sizing.

7.8.4.3 If the expander inlet trip valve is furnished by the purchaser, the vendor shall review the selection and shall provide recommendations concerning the sizing, location, and closing time requirements.

7.8.5 Electric Solenoid Valves

7.8.5.1 Electric solenoid-operated valve(s) shall be provided to initiate operation of the trip valve.

7.8.5.2 The solenoid valve(s) shall be de-energized to trip.

NOTE If solenoids draw high currents that exceed the current rating of the relay in the overspeed shutdown system, interposing relays can be used.

7.8.5.3 The delay response caused by an interposing relay shall be considered in the overall response time.

7.8.5.4 The vendor's design shall include provision for a local manual shutdown mechanism (e.g. push button) located near the expander inlet trip valve.

7.8.5.5 Actuation of the manual shutdown mechanism shall close the trip valve and the variable inlet nozzles.

7.8.5.6 [●] If specified, the vendor shall furnish a local manual shutdown mechanism (i.e. push button) that initiates the expander-compressor shutdown.

7.8.6 Piping and Appurtenances

7.8.6.1 Piping and appurtenances furnished shall be in accordance with 7.8.1 of Part 1 and the following in this section.

7.8.6.2 The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the baseplate.

7.8.6.3 The piping shall terminate with flanged connections at the edge of the baseplate.

7.8.7 Permanent Strainer

7.8.7.1 [●] If specified, a permanent strainer located upstream of the trip valve in a removable spool piece, with an effective free flow area at least twice the cross-sectional area of the expander inlet trip valves shall be furnished by the vendor.

NOTE The allowable pressure drop across and collapse pressure of the strainer should be agreed.

7.8.7.2 [●] If specified, the spool piece and differential pressure instrumentation for the permanent strainer shall be provided.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

Inspection, testing, and preparation for shipment shall be in accordance with Section 8 of Part 1 except as modified below.

8.2 General Requirements

General requirements for inspection, testing, and preparation for shipment shall be in accordance with 8.1 of Part 1. Also refer to Annex E for the Inspector's Checklist.

8.3 Inspection

Requirements for inspection shall be in accordance with 8.2 of Part 1.

8.4 Testing

8.4.1 General

8.4.1.1 In addition to the requirements of 8.3 of Part 1, the expander-compressor(s) shall be tested in accordance with 8.4.3 and 8.4.4. Other optional tests that may be specified are described in 8.4.5.

8.4.1.2 Immediately upon completion of each witnessed mechanical or performance test, copies of the log data recorded during the test shall be given to the witnesses.

8.4.1.3 Expander-compressor(s) with AMBs shall be tested in accordance with requirements of Annex D of Part 1.

8.4.2 Impeller Modal Test

8.4.2.1 For any new design which has not been previously built and tested, an impeller modal test shall be performed.

8.4.2.1.1 The purpose of this test is to verify that the fundamental natural frequency of the blades and disk are in agreement with the range of predicted values calculated during the design phase.

8.4.2.1.2 The measured frequency shall be within ±5 % of the calculated frequency under impeller modal test conditions.

8.4.2.2 If this test does not validate the calculated values, the actual natural frequency shall be assessed against the operating speed range and expected stresses and the need for the agreed corrective action.

8.4.2.3 If it is necessary to modify the impeller to adjust this natural frequency, the modified impeller shall be retested to confirm that the modification was successful.

8.4.2.4 The final report shall show frequencies operating at actual process operating conditions.

8.4.3 Mechanical Running Test

8.4.3.1 The requirements of 8.4.3.1.1 through 8.4.3.1.5 shall be met before the mechanical running test is performed.

8.4.3.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

NOTE Test expander impeller seals can be required due to the temperature differences between operating conditions and test conditions.

8.4.3.1.2 A test compressor impeller that closely matches the weight, center of gravity, and moment of inertia of the actual impeller can be used.

NOTE A test impeller is typically used when the mechanical test would result in temperatures in the compressor that could cause damage to the actual impeller, or the expander cannot produce sufficient power on the test stand to achieve the desired speeds. The test impeller generates less heat and absorbs less power, thereby, eliminating this problem. An alternative way would be to perform the mechanical running test under vacuum for the compressor side.

8.4.3.1.3 If oil-lubricated bearings and/or seals are supplied, 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.

8.4.3.1.4 Oil flow rates shall be measured.

8.4.3.1.5 Oil system components downstream of the filters shall meet the cleanliness requirements of API 614, before any test is started.

8.4.3.1.6 If magnetic bearings are used, the cooling gas to the bearing cavity shall be established, and levitation and tuning of the magnetic bearings shall be checked per the manufacturer's instructions.

8.4.3.2 The mechanical running test of the equipment shall be conducted as specified in 8.4.3.2.1 through 8.4.3.2.5, 8.3.5 of Part 1 for hydrodynamics bearings, and D.6.3 of Part 1 for magnetic bearings.

8.4.3.2.1 The equipment shall be operated at speed increments from zero to the N_{mc} until bearing temperatures, lube-oil temperatures (if applicable), and shaft vibrations have stabilized [1 °C (2 °F) over 10 minutes].

NOTE 1 The vendor will decide on the need for no dwell zones for blade resonances, critical speeds, and other natural frequencies.

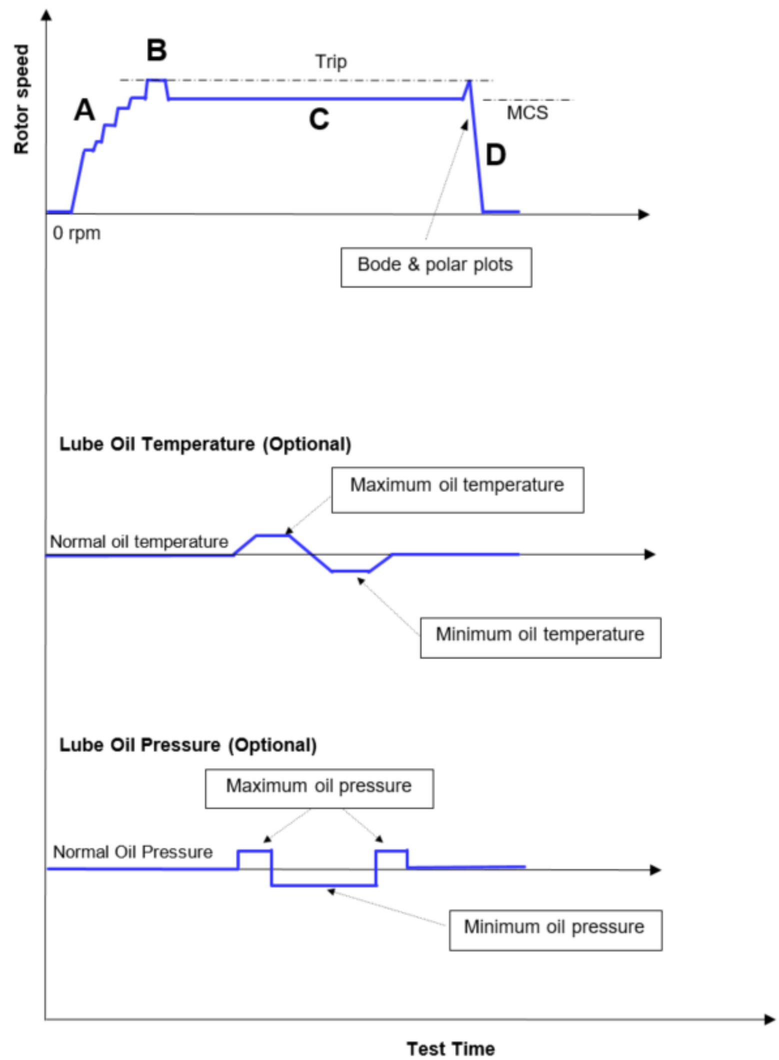
NOTE 2 Refer to Figure 1 for a graphical illustration of the complete mechanical running test.

8.4.3.2.2 The speed shall be increased to trip speed and the equipment shall be run for a minimum of 15 minutes.

8.4.3.2.3 The equipment shall be run for 4 hours continuous operation at N_{mc}.

8.4.3.2.4 The speed shall be increased to trip speed.

8.4.3.2.5 The unit shall be tripped and allowed to coast to a stop.



Key

A warm-up phase

- speed increased multiple increments
- avoid critical speeds, blade frequencies, etc.

B trip speed operation

- 15 minutes

C maximum continuous speed 4-hour test

- oil supply variations performed
- operating conditions recorded

D shutdown/ramp down

- momentary increase to trip speed
- transient operation recorded

Figure 1—Mechanical Running Test

8.4.3.3 During the mechanical running test, the requirements of 8.4.3.3.1 through 8.4.3.3.6, 8.3.5 of Part 1 for hydrodynamics bearings, and D.6.3 of Part 1 for magnetic bearings shall be met.

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

8.4.3.3.1.1 The measured unfiltered vibration shall not exceed the limits of 6.8.7 of Part 1.

8.4.3.3.1.2 The measured unfiltered vibration shall be recorded throughout the operating speed range.

8.4.3.3.1.3 Any other test acceptance criteria shall be agreed and stated in the test agenda.

8.4.3.3.2 While the equipment is operating at N_{mc}, or other speed and/or load that may have been specified in the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous.

8.4.3.3.2.1 As a minimum, these data shall cover a frequency range from 0.25 to 8 times the N_{mc}.

8.4.3.3.2.2 If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in 6.8.9.1 of Part 1 or 6.5 µm (0.25 mil), whichever is greater, the purchaser and the vendor shall agree on requirements for any additional testing and on the equipment's acceptability.

8.4.3.3.3 The mechanical running test shall verify that lateral critical speeds conform to the requirements of 6.8.2.9 of Part 1.

8.4.3.3.4 Any noncritically damped critical speed below the trip speed shall be determined during the mechanical running test and stamped on the nameplate followed by the word "test."

8.4.3.3.5 Shop verification of the unbalanced response analysis is not required.

NOTE Expander-compressors are normally rigid rotor design operating below the first critical speed.

8.4.3.3.6 [●] If specified, all real-time vibration data as agreed by the purchaser and the vendor shall be recorded and a copy provided to the purchaser.

8.4.3.3.7 When spare mechanical center sections including bearing housings are ordered to permit concurrent manufacture, each spare mechanical center section shall also be given a mechanical running test in accordance with the requirements of this standard.

8.4.3.4 [●] For spare rotors and, if specified for main rotors, the requirements of 8.4.3.4.1 through 8.4.3.4.4 shall be met after the mechanical running test is completed.

NOTE Removal of bearings and seals can require disassembly of the machine. The merits of bearing and seal inspection of expander-compressor by dismantling, inspecting, and reassembling the machine are typically evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.

8.4.3.4.1 Hydrodynamic bearings shall be removed, inspected, and reassembled after the mechanical running test is completed.

8.4.3.4.2 [●] If specified, shaft seals shall be removed for inspection following a successful running test.

NOTE Removal and inspection of some seal types (such as cartridges) can require that the seal be returned to the seal manufacturer's facility.

8.4.3.4.3 If replacement or modification of bearings or seals or dismantling of the machine to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable, and the final shop tests shall be run after these replacements or corrections are made.

8.4.3.4.4 If minor scuffs and scratches occur on bearings or process gas seal surfaces, minor cosmetic repairs of these parts is not a cause for rerunning the test.

8.4.4 Assembled Machine Gas Leakage Test

8.4.4.1 After the mechanical running test is completed, each completely assembled machine casing intended for toxic or flammable gas service shall be tested for gas leakage.

8.4.4.1.1 The assembled casing shall be pressurized with an inert gas to the lowest of the expander or compressor casing MAWP, held at this pressure for a minimum of 30 minutes and subjected to a soap bubble test to check for gas leaks.

8.4.4.1.2 The test shall be considered satisfactory when no casing or casing joint leaks are observed.

NOTE 1 These tests are intended to verify the integrity of the casing joints.

NOTE 2 Test gas mole weight will approximate or be less than contract gas mole weight. Helium for low mole weight contract gas and nitrogen or refrigerant gas for high mole weight can be considered.

8.4.4.2 If a post-test inspection of machine internals is required (see 8.4.3.4), these tests shall be performed after machine reassembly following a satisfactory inspection.

8.4.5 Optional Tests

8.4.5.1 General

Refer to 8.3.7 of Part 1 for optional tests.

8.4.5.2 Performance Test

8.4.5.2.1 The expander shall be performance tested at the U/C ratio corresponding to the certified point(s), where:

U is the expander impeller tip speed;

C is the velocity equivalent to the total (stagnation) enthalpy drop across the expander.

8.4.5.2.1.1 Minimum of two points shall be taken to either side of the certified point(s) to establish the expander efficiency parabolic curve.

8.4.5.2.1.2 The measured efficiency at the certified point(s) shall be at least 98 % of the predicted value.

8.4.5.2.2 Permissible deviations from specified operating parameters and conditions (e.g. temperature, pressure, molecular weight, specific volume ratio, flow coefficient, machine Mach number, and machine Reynolds number) as well as any correction required to address these deviations shall be agreed upon before starting the test.

NOTE There is no applicable industry standard test code for expanders. It can be necessary to perform corrections to the data such as when certified point(s) Q/N and U/C cannot be met simultaneously during the test.

8.4.5.2.3 If the expander is the primary objective as defined by 6.1.2, the compressor shall be performance tested at the Q/N ratio corresponding to the certified point(s), where:

Q is the compressor inlet actual volume flow;

N is the speed of the expander-compressor at the certified point.

8.4.5.2.4 The compressor performance test shall be in accordance with ASME PTC 10 or ISO 5389.

8.4.5.2.5 A minimum of five points, including surge and overload, shall be taken at the speed equivalent to the certified speed.

8.4.5.2.6 The compressor shall deliver at least 98 % of the certified head at the certified capacity at the speed derived through power balance from the measured expander efficiency.

8.4.5.2.7 If the compressor is the primary objective as defined by 6.1.3, the compressor shall be performance tested per the requirements of Part 2 of this standard.

8.4.5.2.8 The tolerances shall be inclusive of all test and calculation tolerances.

NOTE Both of the performance test codes referred to have provision for calculating inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore, are not to be further additive.

8.5 Preparation for Shipment

8.5.1 Preparation for shipment shall be in accordance with 8.4 of Part 1 and the following in this section.

8.5.2 When a spare mechanical center section is purchased, it shall be prepared for indoor storage that is not climate controlled for a period of at least 5 years.

NOTE This can require inspection or other activities by the purchaser.

8.5.3 [●] If specified for expander-compressors equipped with magnetic bearings, the main equipment shall be delivered with a “dummy” mechanical center section in place of the actual center section so that the actual center section can be stored for long-term preservation while package installation and plant construction is taking place.

9 Supplier’s Data

9.1 General

9.1.1 Vendor data shall be provided in accordance with Section 9 of Part 1 and the following in this section.

9.1.2 The information to be furnished by the vendor is specified in Annex B and in Section 7 of Part 1.

9.1.3 The vendor shall complete and forward the vendor drawing and data requirements (VDDR) Form (see Annex B) to the address or addresses noted in the inquiry or order.

9.1.4 This form shall detail the schedule for transmission of drawings and data as agreed at the time of the order as well as the number and type of copies required by the purchaser.

9.2 Proposals

9.2.1 General

Requirements for proposals shall be in accordance with I.2 of Part 1.

9.2.2 Technical Data

Technical data shall be in accordance with I.2.3 of Part 1 and the following in this section.

9.2.3 Curves

9.2.3.1 Performance curves shall be submitted for each compressor and expander.

9.2.3.1.1 These curves shall encompass the map of operations, with any limitations indicated thereon.

9.2.3.1.2 All curves shall be marked “PREDICTED.”

9.2.3.2 Predicted curves provided for expander-compressors shall include the following:

a) expander power vs flow;

b) compressor power vs flow;

c) compressor head and pressure ratio vs flow for at least four speed lines from 70 % to 105 % of normal speed;

d) compressor surge line;

e) expander efficiency vs U/C for different Q/N.

9.3 Contract Data

9.3.1 General

Contract data shall be in accordance with I.3 of Part 1 with the following additions in this section.

9.3.2 Curves and Datasheets

9.3.2.1 Curves shall be provided in accordance with I.3.2.1 of Part 1 and 9.3.2.2 below.

9.3.2.2 If a performance test is specified, the vendor shall provide test data and curves when the test has been completed.

9.3.2.2.1 Curves for the as-tested performance shall include the data shown in 9.3.2.1.

9.3.2.2.2 All curves shall be marked “AS TESTED.”

Annex A
(informative)

Datasheets

A representation of the datasheets is enclosed in this annex; however, MS Excel format datasheets have been developed and are available, for purchase from API publications distributors, with this standard. The MS Excel electronic datasheets may have additional functionality over printed hard copies.

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	BY					
TURBOEXPANDER / COMPRESSOR **DATASHEET (API 617-9th, Part 4)** **SI UNITS (bar)**	REV/APPR					
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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
2 FOR ______ UNIT ______
3 SITE ______ PRIMARY SERVICE OBJECTIVE ______
4 SERVICE ______ MODEL: ______
5 MANUFACTURER ______ SERIAL NO. ______
6 APPLICABLE STANDARD: ○ US ○ ISO
7 NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER □ MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)
8 **OPERATING CONDITIONS**

#		NORMAL CASE		CASE A		CASE B	
9							
10	(ALL DATA ON PER UNIT BASIS)	**EXP**	**COMP**	**EXP**	**COMP**	**EXP**	**COMP**
11	**INLET CONDITIONS:**						
12	○ STANDARD VOLUME FLOW (m³/h) (1.013 barA & 0°C DRY)						
13	○ WEIGHT FLOW (kg/h) (EXP: WET / DRY; COMP: WET / DRY)						
14	○ PRESSURE (barA)						
15	○ TEMPERATURE (°C)						
16	○ MOLECULAR WEIGHT						
17	△ GAS PROPERTIES						
18	○ ______						
19	**DISCHARGE CONDITIONS:**						
20	○ PRESSURE (barA)						
21	□ TEMPERATURE (°C)						
22	□ WEIGHT PERCENT LIQUID (%)						
23	□ GAS HORSEPOWER (kW)						
24	□ SPEED (rpm)						
25	□ ADIABATIC / POLYTROPIC EFFICIENCY (Exp / Comp, %)						
26	○ ______						
27	○ ______						
28	○ GUARANTEE CASE (check one case)						

29 **VARIABLE INLET GUIDE VANE PROCESS CONTROL SIGNAL SOURCE:**
30 TYPE: ○ ELECTRONIC RANGE: ______ mA
31 ○ PNEUMATIC ______ (barG)

#	**GAS ANALYSIS:**		**NORMAL**		**CASE A**		**CASE B**		**SEAL**	**REMARKS:**
33	○ MOL % ○ WT %		**EXP**	**COMP**	**EXP**	**COMP**	**EXP**	**COMP**	**GAS**	
34		MW								
35	HELIUM	4.000								
36	HYDROGEN	2.016								
37	NITROGEN	28.016								
38	WATER VAPOR	18.016								
39	CARBON DIOXIDE	44.010								
40	HYDROGEN SULFIDE	34.076								
41	METHANE	16.042								
42	ETHYLENE	28.052								
43	ETHANE	30.068								
44	PROPYLENE	42.078								
45	PROPANE	44.094								
46	I-BUTANE	58.120								
47	n-BUTANE	58.120								
48	I-PENTANE	72.146								
49	n-PENTANE	72.146								
50	HEXANE PLUS									
51										
52	CORROSIVE AGENTS									
53										
54										
55	TOTAL									
56	AVG. MOL. WT.									

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No.		
1	**CONSTRUCTION FEATURES**	
2	☐ **SPEEDS:**	**IMPELLERS:** EXP COMP
3	MAX. CONT. ______ RPM TRIP ______ RPM	☐ DIAMETER (IN.)
4	TIP SPEEDS: EXPANDER ______ (m/s) @ MCS	☐ TYPE (OPEN, ENCLOSED)
5	COMPRESSOR ______ (m/s) @ MCS	☐ TYPE FABRICATION
6	**LATERAL CRITICAL SPEEDS (DAMPED)**	☐ EXPANDER WHEEL MATERIAL
7	☐ FIRST CRITICAL ______ RPM BENDING MODE	☐ YIELD STRENGTH (MPa) MAX ______ MIN ______ (TYP)
8	○ UNDAMPED CRITICAL SPEED MAP	☐ HARDNESS: ______ BNH / R c (TYP)
9	○ COMPLETE ROTORDYNAMIC ANALYSIS (API 617 TYPE)	☐ COMPRESSOR WHEEL MATERIAL ______
10	**CASINGS:**	☐ YIELD STRENGTH (MPa) MAX ______ MIN ______ (TYP)
11	☐ MODEL ______	☐ HARDNESS: ______ BNH / R c (TYP)
12	EXP / BRG HSG / COMP	**SHAFT:**
13	☐ CASING SPLIT	☐ MATERIAL ______
14	☐ MATERIAL	SHAFT END: ☐ TAPERED ☐ CYLINDRICAL
15	☐ ASTM A-351 CF8	☐ YIELD STRENGTH (MPa) ______
16	☐ ASTM A-352 LC3	☐ SHAFT HARDNESS (BNH)(Rc) ______
17	☐ ASTM A-352 LCC	
18	☐ ASTM A-216 WCB	☐ **SHAFT SEALS:**
19	☐ ______	☐ SINGLE PORT BUFFERED LABYRINTH
20	○ R-VALVE SETTING (barG)	☐ DOUBLE PORT BUFFERED LABYRINTH
21	○ MAX. DESIGN TEMP. (°C)	☐ TRIPLE PORT BUFFERED LABYRINTH
22	○ MIN. DESIGN TEMP. (°C)	BLEED PRESSURE: ______ (barG)
23	○ VISUAL INSPECTION	☐ DRY GAS SEAL: ______
24	○ CHARPY TESTING	○ TYPE BUFFER GAS ______
25	○ MAGNETIC PARTICLE	○ BUFFER GAS SUPPLY PRESSURE ______ (barG)
26	○ LIQUID PENETRANT	☐ OTHER ______
27	○ CRITICAL AREA X-RAY	**SEAL GAS REQUIREMENTS:**
28		☐ TYPE: ______
29	______	☐ MIN. SUPPLY PRESS. ______ (barG)
30	☐ HYDROTEST PRESS ☐ 1.5 X DESIGN ☐ ______	☐ MAX. SUPPLY PRESS. ______ (barG)
31	○ CASING LEAK TEST ☐ 1.1 X DESIGN ☐ ______	☐ MIN. SUPPLY TEMP. ______ (°C)
32	○ 100 % NITROGEN	☐ MAX. SUPPLY TEMP. ______ (°C)
33	○ NITROGEN / HELIUM MIX (90 / 10)	☐ NORMAL SUPPLY ______ (m³/h) Δ P ______ (bar)
34	○ 100 % HELIUM	☐ MAX. SUPPLY ______ (m³/h) Δ P ______ (bar)
35	NOTE: LEAK TEST PERFORMED FOLLOWING	NOTE: PURCHASER TO SUPPLY SEAL GAS COMPOSITION ON SHEET 1.
36	HYDROTEST USING SOAP BUBBLE METHOD	

No.	CONNECTION	☐ SIZE NPS / RATING	☐ FACING	☐ POSITION	☐ FLANGED OR STUDDED	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY (m/s)
37	**CASING CONNECTIONS:**						
41	EXPANDER INLET						
42	EXPANDER DISCHARGE						
43	COMPRESSOR INLET						
44	COMPRESSOR DISCHARGE						

45 ☐ **OTHER CONNECTIONS**

No.	SERVICE:	NO.	SIZE	TYPE	SERVICE:	NO.	SIZE	TYPE
47	LUBE-OIL INLET				THRUST PRESSURES			
48	LUBE OIL OUTLET				WHEEL PRESSURES, EX / COM			
	SEAL GAS INLET				BEARING HOUSING PRESS			
49	SEAL GAS OUTLET							
50	CASING DRAINS, EXP / COMP							
51	INTERMEDIATE BLEED							
52								

No.		
53	**CASING DRAINS:**	○ **ALLOWABLE PIPING FORCES AND MOMENTS:**
54	○ PLUGGED ○ FLANGED AND VALVED	○ 1.85 X NEMA SM23
55	○ FLANGED ○ FLANGED, VALVED, AND MANIFOLDED	○ 3 X NEMA SM23
56		○ OTHER: ______

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CONSTRUCTION FEATURES (CONTINUED)

BEARINGS:

RADIAL:	THRUST:
☐ TYPE:	☐ TYPE:
☐ SLEEVE BEARING	☐ TAPERED LAND THRUST BEARING
☐ TILTING PAD BEARING	☐ TILTING PAD THRUST BEARING
○ ACTIVE MAGNETIC BEARING	○ ACTIVE MAGNETIC BEARING
☐ OTHER ______	☐ OTHER ______
☐ MATERIAL:	☐ MANUFACTURER ______
☐ ALUMINUM (BABBITTED)	LUBRICATION: ☐ FLOODED ☐ DIRECTED ☐ N/A
☐ BRASS / BRONZE (BABBITTED)	THRUST COLLAR / DISK: ☐ INTEGRAL ☐ SEPARATE
☐ CARBON STEEL (BABBITTED)	**VIBRATION DETECTORS:**
☐ OTHER ______	TYPE: ☐ EDDY CURRENT ☐ INDUCTIVE ☐ ______
☐ SHAFT DIA. (mm) ______	○ MFR ______
☐ MANUFACTURER	☐ MODEL ______
BEARING TEMPERATURE DEVICES:	○ **LOCATION AND QUANTITY:**
○ **TYPE**	○ NO. PER JOURNAL BEARING ______ TOTAL NO. ______
○ THERMOCOUPLES TYPE: ______	○ IF REQ'D, OSCILLATOR-DEMODULATORS SUPPLIED BY:
○ RESISTANCE TEMP DETECTORS	○ VENDOR ○ MODEL ______
○ RESISTANCE MAT'L ______ ○ ______ OHMS	○ PURCHASER ○ MODEL ______
○ **LOCATION / QTY** ○ RADIAL ○ THRUST	○ **MACHINE VIBRATION PROTECTION LOGIC DEVICE:**
☐ SINGLE DUAL ELEMENT (MAIN & SPARE) ______ PER BRG	○ VIBRATION MONITOR ○ DCS
○ **TEMPERATURE PROTECTION LOGIC DEVICE:**	○ PLC ○ OTHER ______
○ TEMPERATURE MONITOR ○ DCS	○ LOGIC DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
○ PLC ○ OTHER ______	○ LOCATION OF VIBRATION PROTECTION LOGIC DEVICE:
○ LOGIC DEVICE SUPPLIED BY: ○ VENDOR PURCH	○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
○ LOCATION OF TEMPERATURE PROTECTION LOGIC DEVICE:	○ MAIN CONTROL ROOM ○ ______
○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL	○ **VIBRATION AMPLITUDE DISPLAY**
○ MAIN CONTROL ROOM ○ OTHER ______	○ VIBRATION MONITOR ☐ MODEL ______
○ **BEARING TEMPERATURE DISPLAY TYPE:**	○ ALPHANUMERIC DISPLAY
○ TEMPERATURE MONITOR ☐ MODEL ______	○ MMI / VDU
○ ALPHANUMERIC DISPLAY	○ OTHER ______
○ MMI / VDU	○ DISPLAY DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
○ PURCHASER	○ LOCATION OF DISPLAY DEVICE:
○ OTHER ______	○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
○ DISPLAY DEVICE PROVIDED BY: ○ VENDOR ○ PURCH	○ MAIN CONTROL ROOM ○ ______
○ LOCATION OF TEMPERATURE DISPLAY DEVICE:	○ KEY PHASOR ○ YES ○ NO
○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL	**MAGNETIC BEARING CONTROL CABINET, IF REQUIRED**
○ MAIN CONTROL ROOM ○ OTHER ______	○ UPS SUPPLIED BY: ○ VENDOR ○ PURCHASER
	○ **LOCATION OF CONTROL CABINET:**
SPEED PROBES:	○ LOCAL PANEL ○ REMOTE PANEL
○ **TYPE:** ○ ELECTROMAGNETIC ○ EDDY CURRENT	○ MAIN CONTROL ROOM ○ ______
○ **QUANTITY** ______	○ CABLE LENGTH FROM MACHINE SKID
○ **OVERSPEED PROTECTION LOGIC DEVICE (2oo3)**	TO CONTROL CABINET: ______ (m)
○ ______	○ **POWER AND SIGNAL CABLES:**
○ **LOCATION OF SPEED DISPLAY:**	○ SUPPLIED BY PURCHASER ○ SUPPLIED BY VENDOR
○ LOCAL PANEL ○ REMOTE DISPLAY	○ **COMMUNICATION PROTOCOL**
	○ MODBUS ○ OTHER: ______
	☐ POWER CONSUMPTION: (kW)

REMARKS: ______

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ACCESSORIES

EXPANDER INLET TRIP VALVE:

- TYPE:
  - BUTTERFLY VALVE — SIZE: ____ RATING: ____ ALLOWABLE PRESSURE DROP: ____ (bar)
  - OTHER: ____
- DESIGN PRESSURE: ____ (barG) DESIGN TEMPERATURE (MIN / MAX) ____ / ____ (°C)
- MATERIAL:
  - STAINLESS STEEL — LOW TEMP CARBON STEEL — CARBON STEEL — ____
- TRIP VALVE SUPPLIED BY: VENDOR — PURCHASER

INLET SCREENS AND PIPE SPOOLS:

INLET SCREENS:	EXP	COMP
TYPE: (CONE, BASKET, OTHER)		
SIZE (DIA.) (mm)		
MESH SIZE		
PRESSURE DROP (bar)		
MATERIAL:		
STAINLESS STEEL	○	○
OTHER ____	○	○

INLET SCREENS SUPPLIED BY: VENDOR — PURCHASER

INLET SPOOLS FOR INLET SCREENS:	EXP	COMP
SIZE		
RATING		
FACING		
DESIGN PRESSURE: (barG)		
DESIGN TEMPERATURE (MIN/MAX) (°C)		
DESIGN TEMPERATURE (MIN/MAX) (°C)		
MATERIAL:		
STAINLESS STEEL	○	○
LOW TEMP CARBON STEEL	○	○
CARBON STEEL	○	○
OTHER:		
SPOOL CONSTRUCTION:		
SLIP-ON / SOCKETWELD	○	○
SOCKETWELD	○	○
WELDNECK / BUTTWELD	○	○

PIPE SPECIFICATION: ____

COMPRESSOR ANTI-SURGE SYSTEM FURNISHED BY — PURCHASER — SUPPLIER

- CONTROLLER: PID CONTROLLER — OTHER: ____
- RECYCLE VALVE — BY SUPPLIER — SIZING ONLY
  - TYPE: ____ MTL: ____ NOISE LIMIT: VENDOR STD — SPECIAL: ____
  - DESIGN PRESSURE: ____ (barG) DESIGN TEMPERATURE (MIN/MAX) ____ / ____ (°C)
  - PRESSURE UPSTREAM: ____ (barG) DOWNSTREAM ____ (barG)
  - Δ P VALVE ____ (bar) STROKE TIME OPEN - CLOSE ____ (sec) ____
- INLET FLOW DEVICE TYPE: ____ BY: ____
- COMP. INLET FLOW TRANSMITTER — COMP. DIFF. PRESSURE TRANSMITTER
- PIPING: BY PURCHASER — BY SUPPLIER

REMARKS:

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1 **SITE DATA**
2 ○ ELEVATION ______ (m) BAROMETER ______ (barA)
3 ○ RANGE OF AMBIENT TEMPS:
4 NORMAL ______ (°C)
5 MAXIMUM ______ (°C)
6 MINIMUM ______ (°C)
7 **LOCATION:**
8 ○ INDOOR ○ OUTDOOR ○ GRADE
9 ○ HEATED ○ UNDER ROOF ○ MEZZANINE
10 ○ UNHEATED ○ PARTIAL SIDES ○ ______
11 **UNUSUAL CONDITIONS:** ○ DUST ○ FUMES
12 ○ WINTERIZATION REQ'D. ○ TROPICALIZATION REQ'D.
13 ○ OTHER ______
14 ○ INSTRUMENT AND CONTROLS
15 STANDARD ○ NEMA ○ IEC
16 INDOOR OUTDOOR
17 CONTROL ENCLOSURE ______ ______
18 TERMINAL BOX ______ ______

APPLICABLE SPECIFICATIONS:
○ VENDOR STANDARD
○ API 617, 9TH EDITION
○ OTHER: ______
NOISE SPECIFICATIONS:
○ VENDOR STANDARD
○ PURCHASER SPECIFICATION
○ SEE SPECIFICATION ______
ACOUSTIC COVERING: ○ YES ○ NO
○ ELEC. AREA CLASS. ○ NEC ○ IEC
EQUIPMENT
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______
CONTROL PANNELS
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______

19 **SHOP INSPECTION AND TESTS:**

		REQ'D	OBSRV	WTNS
21	CLEANLINESS	●	○	○
22	HYDROSTATIC	●	○	○
23	LOW SPEED BALANCE	●	○	○
24	IMPELLER OVERSPEED (115 % OF MCS)	○	○	○
25	IMPELLER RESONANCE TEST	○	○	○
26	MECHANICAL RUN	○	○	○
27	○ MAIN ○ SPARE			
28	○ CONTRACT PROBES ○ SHOP PROBES			
29	VARY LUBE OIL PRESSURES/TEMPERATURES	○	○	○
30	REASSEMBLING CHECK BALANCING	○	○	○
31	POLAR FORM VIB DATA	○	○	○
32	RECORD VIB DATA	○	○	○
33	DATA TO PURCHASER	○	○	○
34	PERFORMANCE TEST	○	○	○
35	COMPLETE UNIT TEST	○	○	○
36	HE/N2 CASING LEAK TEST	○	○	○
37	SOUND LEVEL TEST	○	○	○
38	FULL POWER TEST	○	○	○
39	SPARE PARTS TEST	○	○	○
40	RESIDUAL UNBALANCE CHECK	○	○	○

○ **UTILITY CONDITIONS:**
INSTRUMENT AIR FOR GUIDE VANE ACTUATOR:
MAX PRESS ______ (barG) MIN PRESS ______ (barG)
MISCELLANEOUS:
☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
AT EXPANDER DISCHARGE: ______
AT COMPRESSOR INLET: ______
○ VENDOR TO REVIEW & COMMENT ON PURCHASER'S PIPING & FOUNDATION
○ VENDOR TO REVIEW & COMMENT ON PURCHASER'S CONTROL SYSTEMS
○ SHAFT SEALS REMOVED FOR INSPECTION FOLLOWING MRT
○ DUMMY MECHANICAL CENTER SECTION INSTALLED
○ ______
○ ______

☐ **WEIGHTS** (kg)
EXP / COMP UNIT ______ (kg)
MAINTENANCE (SPARE ROTATING ASSY) ______ (kg)
TOTAL MACHINERY SKID WEIGHT: ______ (kg)
TOTAL SUPPORT SYSTEM SKID WT. (IF SEPARATE): ______ (kg)

☐ **SPACE REQUIREMENTS** (m)
MACHINERY SKID: L ______ W ______ H ______
SUPPORT SYSTEM SKID: L ______ W ______ H ______

41 **PAINTING:**
42 ○ VENDOR STANDARD
43 ○ OTHER ______
44
45 **SHIPPING PREPARATION:**
46 ○ DOMESTIC PACKING
47 ○ EXPORT PACKING (MIL-P 116J METHOD II)
48 ○ SPECIAL: ______
49 **SPARE ROTATING ASSEMBLY:**
50 ○ WOODEN SHIPPING CONTAINER
51 ○ METAL STORAGE CONTAINER
52 ○ N2 PURGE ○ OTHER:

SPECIAL TOOL PACKAGING
○ METAL STORAGE CONTAINER
○ OTHER: ______

DELIVERY:
○ FCA FACTORY
○ FOB SITE (DOMESTIC ONLY)
○ OTHER: ______

53 **REMARKS:** ______
54 ______
55 ______
56 ______

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	BY					
TURBOEXPANDER / COMPRESSOR DATASHEET (API 617-9th, Part 4) US CUSTOMARY	REV/APPR					
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1 APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
2 FOR ______ UNIT ______
3 SITE ______ PRIMARY SERVICE OBJECTIVE ______
4 SERVICE ______ MODEL: ______
5 MANUFACTURER ______ SERIAL NO. ______
6 APPLICABLE STANDARD: ○ US ○ ISO
7 NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER □ MANUFACTURER △ AGREEMENT (PRIOR TO PURCHASE)

8 **OPERATING CONDITIONS**

		NORMAL CASE		CASE A		CASE B	
9							
10	(ALL DATA ON PER UNIT BASIS)	EXP	COMP	EXP	COMP	EXP	COMP
11	**INLET CONDITIONS:**						
12	○ STD VOLUME FLOW (MMSCFD/SCFM -14.7 psia & 60°F DRY)						
13	○ WEIGHT FLOW (lb/hr) (EXP: WET / DRY; COMP: WET / DRY)						
14	○ PRESSURE (psia)						
15	○ TEMPERATURE (°F)						
16	○ MOLECULAR WEIGHT						
17	△ GAS PROPERTIES ______						
18	○ ______						
19	**DISCHARGE CONDITIONS:**						
20	○ PRESSURE (psia)						
21	□ TEMPERATURE (°F)						
22	□ WEIGHT PERCENT LIQUID (%)						
23	□ GAS HORSEPOWER (HP)						
24	□ SPEED (rpm)						
25	□ ADIABATIC / POLYTROPIC EFFICIENCY (Exp / Comp, %)						
26	○ ______						
27	○ ______						
28	○ GUARANTEE CASE (check one case)						

29 **VARIABLE INLET GUIDE VANE PROCESS CONTROL SIGNAL SOURCE:**
30 TYPE: ○ ELECTRONIC RANGE: ______ mA
31 ○ PNEUMATIC ______ (psig)

			NORMAL		CASE A		CASE B		SEAL	REMARKS:
32	**GAS ANALYSIS:**									
33	○ MOL % ○ WT %		EXP	COMP	EXP	COMP	EXP	COMP	GAS	
34		MW								
35	HELIUM	4.000								
36	HYDROGEN	2.016								
37	NITROGEN	28.016								
38	WATER VAPOR	18.016								
39	CARBON DIOXIDE	44.010								
40	HYDROGEN SULFIDE	34.076								
41	METHANE	16.042								
42	ETHYLENE	28.052								
43	ETHANE	30.068								
44	PROPYLENE	42.078								
45	PROPANE	44.094								
46	I-BUTANE	58.120								
47	n-BUTANE	58.120								
48	I-PENTANE	72.146								
49	n-PENTANE	72.146								
50										
51	CORROSIVE AGENTS									
52										
53										
54										
55	TOTAL									
56	AVG. MOL. WT.									

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1 **CONSTRUCTION FEATURES**

2 ☐ **SPEEDS:**
3 MAX. CONT. ______ RPM TRIP ______ RPM
4 TIP SPEEDS: EXPANDER ______ (fps) @ MCS
5 COMPRESSOR ______ (fps) @ MCS
6 **LATERAL CRITICAL SPEEDS (DAMPED)**
7 ☐ FIRST CRITICAL ______ RPM BENDING MODE
8 ○ UNDAMPED CRITICAL SPEED MAP
9 ○ COMPLETE ROTORDYNAMIC ANALYSIS (API 617 TYPE)
10 **CASINGS:**
11 ☐ MODEL ______

12		EXP	BRG HSG	COMP
13	☐ CASING SPLIT			
14	☐ MATERIAL			
15	☐ ASTM A-351 CF8			
16	☐ ASTM A-352 LC3			
17	☐ ASTM A-352 LCC			
18	☐ ASTM A-216 WCB			
19	☐ ______			
20	○ R-VALVE SETTING (PSIG)			
21	○ MAX. DESIGN TEMP. (°F)			
22	○ MIN. DESIGN TEMP. (°F)			
23	○ VISUAL INSPECTION			
24	○ CHARPY TESTING			
25	○ MAGNETIC PARTICLE			
26	○ LIQUID PENETRANT			
27	○ CRITICAL AREA X-RAY			
28	○ ______			
29	______			

30 ☐ HYDROTEST PRESS ☐ 1.5 X DESIGN ☐ ______
31 ○ CASING LEAK TEST ☐ 1.1 X DESIGN ☐ ______
32 ○ 100 % NITROGEN
33 ○ NITROGEN / HELIUM MIX (90 / 10)
34 ○ 100 % HELIUM
35 NOTE: LEAK TEST PERFORMED FOLLOWING
36 HYDROTEST USING SOAP BUBBLE METHOD

	EXP	COMP
IMPELLERS:		
☐ DIAMETER (IN.)		
☐ TYPE (OPEN, ENCLOSED)		
☐ TYPE FABRICATION		

☐ EXPANDER WHEEL MATERIAL
☐ YIELD STRENGTH (ksi) MAX ______ MIN ______ (TYP)
☐ HARDNESS: ______ BNH / R_c (TYP)
☐ COMPRESSOR WHEEL MATERIAL ______
☐ YIELD STRENGTH (ksi) MAX ______ MIN ______ (TYP)
☐ HARDNESS: ______ BNH / R_c (TYP)

SHAFT:
☐ MATERIAL ______
SHAFT END: ☐ TAPERED ☐ CYLINDRICAL
☐ YIELD STRENGTH (ksi) ______
☐ SHAFT HARDNESS (BNH)(Rc) ______

☐ **SHAFT SEALS:**
☐ SINGLE PORT BUFFERED LABYRINTH
☐ DOUBLE PORT BUFFERED LABYRINTH
☐ TRIPLE PORT BUFFERED LABYRINTH
BLEED PRESSURE: ______ (psig)
☐ DRY GAS SEAL: ______
○ TYPE BUFFER GAS ______
○ BUFFER GAS SUPPLY PRESSURE ______ (psig)
☐ OTHER ______

SEAL GAS REQUIREMENTS :
☐ TYPE: ______
☐ MIN. SUPPLY PRESS. ______ (psig)
☐ MAX. SUPPLY PRESS. ______ (psig)
☐ MIN. SUPPLY TEMP. ______ (°F)
☐ MAX. SUPPLY TEMP. ______ (°F)
☐ NORMAL SUPPLY ______ (scfm) Δ P ______ (psi)
☐ MAX. SUPPLY ______ (scfm) Δ P ______ (psi)
NOTE: PURCHASER TO SUPPLY SEAL GAS COMPOSITION ON SHEET 1.

37 **CASING CONNECTIONS:**

38–40	CONNECTION	☐ SIZE NPS / RATING	☐ FACING	☐ POSITION	☐ FLANGED OR STUDDED	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY (fps)
41	EXPANDER INLET						
42	EXPANDER DISCHARGE						
43							
44							

45 ☐ **OTHER CONNECTIONS**

46	SERVICE:	NO.	SIZE	TYPE
47	LUBE-OIL INLET			
48	LUBE OIL OUTLET			
	SEAL GAS INLET			
49	SEAL GAS OUTLET			
50	CORROSIVE AGENTS			
51	INTERMEDIATE BLEED			

SERVICE:	NO.	SIZE	TYPE
THRUST PRESSURES			
WHEEL PRESSURES, EX / COM			
BEARING HOUSING PRESS			
______			
______			
______			

52
53 **CASING DRAINS:**
54 ○ PLUGGED ○ FLANGED AND VALVED
55 ○ FLANGED ○ FLANGED, VALVED, AND MANIFOLDED
56

○ **ALLOWABLE PIPING FORCES AND MOMENTS:**
○ 1.85 X NEMA SM23
○ 3 X NEMA SM23
○ OTHER: ______

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CONSTRUCTION FEATURES (CONTINUED)

BEARINGS:

RADIAL:

- ☐ TYPE:
  - ☐ SLEEVE BEARING
  - ☐ TILTING PAD BEARING
  - ○ ACTIVE MAGNETIC BEARING
  - ☐ OTHER ______
- ☐ MATERIAL:
  - ☐ ALUMINUM (BABBITTED)
  - ☐ BRASS / BRONZE (BABBITTED)
  - ☐ CARBON STEEL (BABBITTED)
  - ☐ OTHER ______
- ☐ SHAFT DIA. (in.) ______
- ☐ MANUFACTURER

BEARING TEMPERATURE DEVICES:

- ○ TYPE
  - ○ THERMOCOUPLES TYPE: ______
  - ○ RESISTANCE TEMP DETECTORS
    - ○ RESISTANCE MAT'L ______ ○ ______ ______ OHMS
- ○ LOCATION / QTY ○ RADIAL ○ THRUST
  - ☐ SINGLE DUAL ELEMENT (MAIN & SPARE) ______ PER BRG
- ○ TEMPERATURE PROTECTION LOGIC DEVICE:
  - ○ TEMPERATURE MONITOR ○ DCS
  - ○ PLC ○ OTHER ______
  - ○ LOGIC DEVICE SUPPLIED BY: ○ VENDOR PURCH
  - ○ LOCATION OF TEMPERATURE PROTECTION LOGIC DEVICE:
  - ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
  - ○ MAIN CONTROL ROOM ○ OTHER ______
- ○ BEARING TEMPERATURE DISPLAY TYPE:
  - ○ TEMPERATURE MONITOR ☐ MODEL ______
  - ○ ALPHANUMERIC DISPLAY
  - ○ MMI / VDU
  - ○ PURCHASER
  - ○ OTHER ______
- ○ DISPLAY DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
  - ○ LOCATION OF TEMPERATURE DISPLAY DEVICE:
  - ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
  - ○ MAIN CONTROL ROOM ○ OTHER ______

SPEED PROBES:

- ○ TYPE: ○ ELECTROMAGNETIC ○ EDDY CURRENT
- ○ QUANTITY
- ○ OVERSPEED PROTECTION TO LOGIC DEVICE (2oo3)
  - ○ ______
- ○ LOCATION OF SPEED DISPLAY:
  - ○ LOCAL PANEL ○ REMOTE DISPLAY

THRUST:

- ☐ TYPE:
  - ☐ TAPERED LAND THRUST BEARING
  - ☐ TILTING PAD THRUST BEARING
  - ○ ACTIVE MAGNETIC THRUST BEARING
  - ☐ OTHER ______
- ☐ MANUFACTURER ______
- LUBRICATION: ☐ FLOODED ☐ DIRECTED ☐ N/A
- THRUST COLLAR / DISK: ☐ INTEGRAL ☐ SEPARATE

VIBRATION DETECTORS:

- TYPE: ☐ EDDY CURRENT ☐ INDUCTIVE ☐ ______
  - ○ MFR ______
  - ☐ MODEL ______
- ○ LOCATION AND QUANTITY:
  - ○ NO. PER JOURNAL BEARING ______ TOTAL NO. ______
  - ○ IF REQ'D, OSCILLATOR-DEMODULATORS SUPPLIED BY:
    - ○ VENDOR ○ MODEL ______
    - ○ PURCHASER ○ MODEL ______
- ○ MACHINE VIBRATION PROTECTION LOGIC DEVICE:
  - ○ VIBRATION MONITOR ○ DCS
  - ○ PLC ○ OTHER ______
  - ○ LOGIC DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
  - ○ LOCATION OF VIBRATION PROTECTION LOGIC DEVICE:
  - ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
  - ○ MAIN CONTROL ROOM ○ ______
- ○ VIBRATION AMPLITUDE DISPLAY
  - ○ VIBRATION MONITOR ☐ MODEL ______
  - ○ ALPHANUMERIC DISPLAY
  - ○ MMI / VDU
  - ○ OTHER ______
  - ○ DISPLAY DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
  - ○ LOCATION OF DISPLAY DEVICE:
  - ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
  - ○ MAIN CONTROL ROOM ○ ______
- ○ KEY PHASOR ○ YES ○ NO

MAGNETIC BEARING CONTROL CABINET, IF REQUIRED

- ○ UPS SUPPLIED BY: ○ VENDOR ○ PURCHASER
- ○ LOCATION OF CONTROL CABINET:
  - ○ LOCAL PANEL ○ REMOTE PANEL
  - ○ MAIN CONTROL ROOM ○ ______
- ○ CABLE LENGTH FROM MACHINE SKID TO CONTROL CABINET: ______ (ft)
- ○ POWER AND SIGNAL CABLES:
  - ○ SUPPLIED BY PURCHASER ○ SUPPLIED BY VENDOR
- ○ COMMUNICATION PROTOCOL
  - ○ MODBUS ○ OTHER: ______
- ☐ POWER CONSUMPTION: (HP)

REMARKS: ______

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ACCESSORIES

○ **EXPANDER INLET TRIP VALVE:**
○ TYPE:
○ BUTTERFLY VALVE ○ SIZE: ______ ○ RATING: ______ ○ ALLOWABLE PRESSURE DROP: ______ (psi)
○ OTHER: ______
○ DESIGN PRESSURE: ______ (psig) ○ DESIGN TEMPERATURE (MIN / MAX) ______ / ______ (°F)
○ MATERIAL:
○ STAINLESS STEEL ○ LOW TEMP CARBON STEEL ○ CARBON STEEL ○ OTHER: ______
○ TRIP VALVE SUPPLIED BY: ○ VENDOR ○ PURCHASER

○ **INLET SCREENS AND PIPE SPOOLS:**

INLET SCREENS:	EXP	COMP
TYPE: (CONE, BASKET, OTHER)		
SIZE (DIA.) (in.)		
MESH SIZE		
PRESSURE DROP (psi)		
MATERIAL:		
STAINLESS STEEL	○	○
OTHER ______	○	○

INLET SCREENS SUPPLIED BY: ○ VENDOR ○ PURCHASER

INLET SPOOLS FOR INLET SCREENS:	EXP	COMP
SIZE		
RATING		
FACING		
DESIGN PRESSURE: (psig)		
DESIGN TEMPERATURE (MIN/MAX) (°F)		
DESIGN TEMPERATURE (MIN/MAX) (°F)		
MATERIAL:		
STAINLESS STEEL	○	○
LOW TEMP CARBON STEEL	○	○
CARBON STEEL	○	○
OTHER:		
SPOOL CONSTRUCTION:		
SLIP-ON / SOCKETWELD	○	○
SOCKETWELD	○	○
WELDNECK / BUTTWELD	○	○

PIPE SPECIFICATION: ______

○ **COMPRESSOR ANTI-SURGE SYSTEM** FURNISHED BY ○ PURCHASER ☐ SUPPLIER
○ CONTROLLER: ○ PID CONTROLLER ○ OTHER: ______
○ RECYCLE VALVE ○ BY SUPPLIER ○ SIZING ONLY
TYPE: ______ MTL: ______ NOISE LIMIT: ○ VENDOR STD ○ SPECIAL: ______
○ DESIGN PRESSURE: ______ (psig) ○ DESIGN TEMPERATURE (MIN/MAX) ______ / ______ (°F)
PRESSURE UPSTREAM: ______ (psig) DOWNSTREAM ______ (psig)
☐ Δ P VALVE ______ (psi) STROKE TIME OPEN - CLOSE ______ (sec)
○ INLET FLOW DEVICE TYPE: ______ ○ BY: ______
○ COMP. INLET FLOW TRANSMITTER ○ COMP. DIFF. PRESSURE TRANSMITTER
○ PIPING: ○ BY PURCHASER ○ BY SUPPLIER

REMARKS: ______

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SITE DATA

○ ELEVATION ______ (ft) BAROMETER ______ (psia)
○ RANGE OF AMBIENT TEMPS:
NORMAL ______ (°F)
MAXIMUM ______ (°F)
MINIMUM ______ (°F)

LOCATION:

○ INDOOR ○ OUTDOOR ○ GRADE
○ HEATED ○ UNDER ROOF ○ MEZZANINE
○ UNHEATED ○ PARTIAL SIDES ○ ______

UNUSUAL CONDITIONS: ○ DUST ○ FUMES
○ WINTERIZATION REQ'D. ○ TROPICALIZATION REQ'D.
○ OTHER ______

INSTRUMENT AND CONTROLS
STANDARD ○ NEMA ○ IEC

	INDOOR	OUTDOOR
CONTROL ENCLOSURE	______	______
TERMINAL BOX	______	______

SHOP INSPECTION AND TESTS:

	REQ'D	OBSRV	WTNS
CLEANLINESS	●	○	○
HYDROSTATIC	●	○	○
LOW SPEED BALANCE	●	○	○
IMPELLER OVERSPEED (115 % OF MCS)	○	○	○
IMPELLER RESONANCE TEST	○	○	○
MECHANICAL RUN	○	○	○
○ MAIN ○ SPARE			
○ CONTRACT PROBES ○ SHOP PROBES			
VARY LUBE OIL PRESSURES & TEMPERATURES	○	○	○
REASSEMBLY CHECK BALANCE			
POLAR FORM VIB DATA	○	○	○
RECORD VIB DATA	○	○	○
DATA TO PURCHASER	○	○	○
PERFORMANCE TEST	○	○	○
COMPLETE UNIT TEST	○	○	○
HE/N2 CASING LEAK TEST	○	○	○
SOUND LEVEL TEST	○	○	○
FULL POWER TEST	○	○	○
SPARE PARTS TEST	○	○	○
RESIDUAL UNBALANCE CHECK	○	○	○

PAINTING:

○ VENDOR STANDARD
○ OTHER ______

SHIPPING PREPARATION:

○ DOMESTIC PACKING
○ EXPORT PACKING (MIL-P 116J METHOD II)
○ SPECIAL: ______

SPARE ROTATING ASSEMBLY:

○ WOODEN SHIPPING CONTAINER
○ METAL STORAGE CONTAINER
○ N2 PURGE ○ OTHER:

APPLICABLE SPECIFICATIONS:

○ VENDOR STANDARD
○ API 617, 9TH EDITION
○ OTHER: ______

NOISE SPECIFICATIONS:

○ VENDOR STANDARD
○ PURCHASER SPECIFICATION
○ SEE SPECIFICATION ______

ACOUSTIC COVERING: ○ YES ○ NO

○ ELEC. AREA CLASS. ○ NEC ○ IEC

EQUIPMENT
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______

CONTROL PANNELS
CLASS ______ GROUP ______ DIV. ______
ZONE ______ GROUP ______ TEMP CLASS ______

○ **UTILITY CONDITIONS:**

INSTRUMENT AIR FOR GUIDE VANE ACTUATOR:

MAX PRESS ______ (psig) MIN PRESS ______ (psig)

MISCELLANEOUS:

☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
AT EXPANDER DISCHARGE: ______
AT COMPRESSOR INLET: ______
○ VENDOR TO REVIEW & COMMENT ON PURCHASER'S PIPING & FOUNDATION
○ VENDOR TO REVIEW & COMMENT ON PURCHASER'S CONTROL SYSTEMS
○ SHAFT SEALS REMOVED FOR INSP. FOLLOWING MECH. TEST
○ DUMMY MECHANICAL CENTER SECTION INSTALLED
○ ______

☐ **WEIGHTS** (lbm)

EXP / COMP UNIT ______ (lbm)
MAINTENANCE (SPARE ROTATING ASSY) ______ (lbm)
TOTAL MACHINERY SKID WEIGHT: ______ (lbm)
TOTAL SUPPORT SYSTEM SKID WT. (IF SEPARATE): ______ (lbm)

☐ **SPACE REQUIREMENTS** (ft)

MACHINERY SKID: L ______ W ______ H ______
SUPPORT SYSTEM SKID: L ______ W ______ H ______

SPECIAL TOOL PACKAGING
○ METAL STORAGE CONTAINER
○ OTHER: ______

DELIVERY:

○ FCA FACTORY
○ FOB SITE (DOMESTIC ONLY)
○ OTHER: ______

REMARKS: ______

Annex B
(normative)

Vendor Drawing and Data Requirements

B.1 VDDR for Expander-compressors and Expander-generators (See Text for Details of the Description)

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]— Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	**Distribution Record** Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	1. Certified dimensional outline drawing and list of connections					
/	/	/	2. Cross-sectional drawings and part numbers					
/	/	/	3. Rotor assembly drawings and part numbers					
/	/	/	4. Thrust-bearing assembly drawings and part numbers					
/	/	/	5. Radial-bearing assembly drawings and bill of materials					
/	/	/	6. Coupling assembly drawings and bill of materials (for expander-generators)					
/	/	/	7. Lube-oil system schematic and bill of materials					
/	/	/	8. Lube-oil system arrangement drawing and list of connections					
/	/	/	9. Lube-oil system component drawings and data					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.
[b] Purchase may indicate in the column the desired time frame for submission of data.
[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]— Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	10. Seal/buffer/cooling gas system schematic and bill of materials					
/	/	/	11. Seal/buffer/cooling gas system arrangement drawing and list of connections					
/	/	/	12. Seal/buffer/cooling gas system component drawings and data					
/	/	/	13. Seal assembly drawing and part numbers					
/	/	/	14. Electrical and instrumentation schematics and bill of materials					
/	/	/	15. Electrical and instrumentation arrangement drawing and list of connections					
/	/	/	16. Datasheets (proposal/as-built)					

a Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

b Purchase may indicate in the column the desired time frame for submission of data.

c Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

			Description (see text)	**Distribution Record**				
				Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	17. Allowable external forces and moments for each nozzle in tabular form (proposal/as-built)					
/	/	/	18. Predicted noise sound level (proposal)					
/	/	/	19. Lateral analysis report					
/	/	/	20. Torsional analysis report (for expander-generators)					
/	/	/	21. Predicted performance curves					
/	/	/	22. Impeller overspeed test report					
/	/	/	23. Mechanical running test report					
/	/	/	24. Coupling selection and rating (for expander-generators)					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	25. List of recommended spare parts					
/	/	/	26. List of special tools					
/	/	/	27. Preparation for storage and preservation at job site before installation					
/	/	/	28. Weather protection required at job site					
/	/	/	29. Tabulation of all utilities					
/	/	/	30. List of similar machines (with the proposal)					
/	/	/	31. Operating restrictions to protect equipment during start-up operation and shutdown					
/	/	/	32. List of components requiring purchaser's approval					
/	/	/	33. Summary of NACE compliant materials					

Distribution Record: columns 5–9.

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

Proposal	Review	Final	**Description** (see text)	Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	34. Seal/Buffer/Cooling gas consumption rates					
/	/	/	35. Drawings, details, and description of instrumentation and controls					
/	/	/	36. Drawings, details, and operation of heat exchangers					
/	/	/	37. Statement of manufacturer's testing capabilities (with the proposal)					
/	/	/	38. Performance test data and curves (as-built)					

Distribution Record applies to the last five columns.

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

Proposal [a]—Bidder shall furnish number of paper copies/number of electronic copies of data as indicated.
Review—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.
Final—Vendor shall furnish number of paper copies/number of electronic copies of data as indicated.

			Description (see text)	**Distribution Record**				
				Review Due from Vendor [b c]	Review Received from Vendor	Review Returned to Vendor	Final Due from Vendor [c]	Final Received from Vendor
/	/	/	39. Production/delivery schedule					
/	/	/	40. Testing procedures					
/	/	/	41. Progress reports					
/	/	/	42. Installation manual					
/	/	/	43. Operating and maintenance manual					
/	/	/	44. Technical data manual (e.g. test reports, component documentations)					
/	/	/	45. Interconnecting cable specification for magnetic bearing systems					
/	/	/	46. Magnetic bearing electrical interface drawing					
/	/	/	47. Magnetic bearing system arrangement, component drawings, and data					
/	/	/	48. Magnetic bearing control cabinet technical description drawing, components, etc.					
/	/	/	49. Magnetic bearing data					

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR AND EXPANDER-GENERATOR VENDOR DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No. ....
	Purchase Order No.	Date ....
	Requisition No.	Date ....
	Inquiry No.	Date ....
	Revision by	Manufacturer ....
	For	Unit ....
	Site	Service ....

1. Where necessary to meet the scheduled shipping date, with mutual agreement, the vendor may proceed with manufacture upon receipt of the order and without awaiting the purchaser's approval of drawings.

2. The vendor shall send all drawings and data to the following:

____

____

____

3. All drawings and data shall show project, purchase order, and item numbers as well as plant location and unit. One set of the drawings and instructions necessary for field installation, in addition to the copies specified above, shall be forwarded with shipment.

4. See the descriptions of required items that follow.

5. All of the information indicated on the distribution schedule shall be received before final payment is made.

6. If typical drawings, schematics, and bills of material are used for proposals, they shall be marked up to show the expected weight and dimensions to reflect the actual equipment and scope proposed.

Nomenclature:

S number of weeks before shipment

F number of weeks after firm order

D number of weeks after receipt of approved drawings

Vendor____

Date___________________ Vendor Reference ______________________________________

Signature____

(Signature acknowledges receipt of all instructions)

B.2 Descriptions

1) Certified dimensional outline drawing and list of connections, including the following:
   a) the size, rating, and location of all customer connections;
   b) approximate overall and handling weights;
   c) overall dimensions and maintenance and dismantling clearances;
   d) shaft centering height to account for thermal growth (for expander-generators);
   e) dimensions of baseplate (if furnished) for train or skid mounted package, complete with diameters, number and locations of bolt holes, and thicknesses of sections through which the bolts pass;
   f) grounding details;
   g) forces and moments allowed for suction and discharge nozzles;
   h) center of gravity and lifting points;
   i) shaft end separation and alignment data;
   j) direction of rotation (for expander-generators);
   k) winterization, tropicalization, and/or noise attenuation details, when required;
   l) sketches to show lifting of assembled machine and major components and auxiliaries.
2) Cross-sectional drawings and part numbers of major equipment.
3) Rotor assembly drawings and part numbers.
4) Thrust-bearing assembly drawings and part numbers.
5) Radial-bearing assembly drawings and bill of materials.
6) Coupling assembly drawing and bill of materials (for expander-generators).
7) Lube-oil system schematic and bill of materials, including the following:
   a) oil flows, temperatures, and pressure at each point;
   b) control alarm and shutdown settings for pressure and temperature;
   c) total heat loads;
   d) utility requirements, including electrical, water, air, and steam;
   e) pipe, valve, and orifice sizes;
   f) instrumentation, safety devices, control schemes, and wiring diagrams.
8) Lube-oil system arrangement drawing and list of connections.

9) Lube-oil system component drawings and data, including the following:

   a) pumps and drivers;

   b) heat exchangers, filter, accumulator, and reservoir;

   c) instrumentation.

10) Seal/buffer/cooling gas system schematic and bill of materials, including the following:

   a) flows, temperatures, and pressures at each point;

   b) control, alarm, and shutdown settings for pressure and temperatures;

   c) total heat load for heat exchangers, if required;

   d) utility requirements, including electrical, water, and instrument air;

   e) pipe, valve, and orifice sizes;

   f) instrumentation, safety devices, control schemes, and wiring diagrams;

   g) filtration requirements.

11) Seal/buffer/cooling gas system arrangement drawing and list of connections.

12) Seal/buffer/cooling gas system components drawing and data, including the following:

   a) boosters and drivers;

   b) heat exchangers, filters, and heaters;

   c) instrumentation.

13) Seal assembly drawing and part numbers.

14) Electrical and instrumentation schematics and bill of materials.

15) Electrical and instrumentation arrangement drawing and list of connections:

   a) vibration warning and shutdown limits;

   b) bearing temperature warning and shutdown limits;

   c) lube-oil temperature warning and shutdown limits;

   d) lube-oil pressure warning and shutdown limits;

   e) lube-oil level warning and shutdown limits;

   f) machine discharge pressure and temperature warning and shutdown limits;

   g) seal, pressure, temperature, flow warning, and shutdown limits.

16) Datasheets (proposal/as-built).

17) The vendor shall furnish the allowable forces and moments for each nozzle in tabular form (proposal/as-built).

18) Predicted noise level, sound pressure, and sound power level.

19) Lateral analysis report when specified shall also include a stability analysis.

20) Torsional analysis report (for expander-generators).

21) Performance data and curves shall be submitted to the purchaser (proposal/as-built).

22) Dimensions taken from each impeller before and after overspeed testing shall be submitted for review.

23) Mechanical running test report to include the following:

    a) unfiltered vibration;

    b) plots showing synchronous vibration and phase angle, filtered and unfiltered;

    c) when specified, data shall be furnished in polar form;

    d) when specified, digital recordings shall be made of all real time vibration data;

    e) electrical and mechanical runout at each probe.

    Immediately upon completion of each witnessed mechanical or performance test, copies of the log and data recorded during the test shall be given to the witnesses.

24) Coupling selection and rating (for expander-generators).

25) List of spare parts recommended for start-up and normal maintenance purposes.

26) List of the special tools furnished for maintenance.

27) The vendor shall provide the purchaser with instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and prior to start-up.

28) A description of any special weather protection required for start-up, operation, and period of idleness under the site conditions specified on the datasheets.

29) A complete list of utility requirements: quantity, filtration, and supply pressure of the following:

    a) steam;

    b) water;

    c) electricity;

    d) air;

    e) gas;

    f) lube oil and seal oil (quantity and supply pressure);

    g) heat loads;

    h) power ratings and operating power requirements for auxiliary drivers.

30) A list of machines similar to the proposed machines that have been installed and operating under conditions analogous to those specified in the inquiry.

31) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment, including any undesirable speeds due to natural frequencies.

32) A list of any components that can be construed as being of alternative design, requiring purchaser's acceptance.

33) A summary of the materials of construction for the expander-compressor, including hardness for materials exposed to H_2S.

34) The maximum seal/buffer/cooling gas consumption rates (injection or eduction) and rated or expected inner seal-oil leakage rates, if applicable. If self-acting dry gas seals are supplied, expected seal gas consumption, minimum seal gas supply flow and primary vent flow should be given at maximum sealing pressure and at conditions over the operating envelope of the machine.

35) Drawings, details, and descriptions of the operations of instrumentation and controls as well as the makes, materials, and type of auxiliary equipment. The vendor shall also include a complete description of the alarm and shutdown facilities to be provided.

36) If heat exchangers are furnished, the vendor shall provide the following:

    a) drawing showing cooling system details;

    b) data for purchaser heat and material balances;

    c) details of provisions for separating and withdrawing condensate;

    d) vendor's recommendations regarding provision for support and piping expansion.

37) A statement of the manufacturer's capability regarding testing (including performance testing) of the expander-compressor (or expander-generator) and any other specified items on the train. Details of each optional test specified shall be included with the proposal.

38) Predicted performance curves shall be provided per 9.2.3.

39) The vendor shall provide production and delivery schedules.

40) The vendor shall submit detailed procedures, including acceptance criteria for all mandatory and optional tests, at least 6 weeks prior to the first running test.

41) The vendor shall submit progress reports.

42) All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of final certified drawings.

43) A manual containing all required operating and maintenance instructions shall be supplied not later than 2 weeks after all specified test shall have been successfully completed.

44) The vendor shall provide a "technical data manual within 30 days of completion" of shop testing, including the following:

a) necessary certification of materials;

b) purchase specification for all items on the bill of materials;

c) test data to verify requirements of specifications have been met;

d) heat treat records;

e) results of quality test and inspections;

f) mechanical running test data log;

g) final assembly maintenance and running clearances.

The vendor is also required to keep these data available for examination by the purchaser upon request, for at least 5 years.

45) Interconnecting cable specification for magnetic bearing systems, including cable length, number of conductors, cross-sectional area, linear capacitance, shielding, armouring, and segregation requirements.

46) Magnetic bearing electrical interface drawing defines all terminal points and connections between the magnetic bearing control cabinet, magnetic bearings, and the plant control system and identifies installation segregation requirements. It shows the location of connection in any junction box, pressure pass-through, and connectors. It may also show the electrical area classification.

47) The magnetic bearing system arrangement, sometimes called the mechanical interface drawing, shows all the detailed dimensional fit-up information at the interface between the magnetic bearing components and the bearing housing and rotor. This drawing also shows the spatial orientation and location of all cabling and leads egressing the magnetic bearing mechanical components.

48) The magnetic bearing control cabinet technical description contains the required information to install and operate the cabinet. The technical description includes a physical description, which contains a dimensioned drawing of the enclosure with mass, center of gravity, and lifting points. The technical description also includes:

a) all requirements for packing, shipping, preservation, storage, and installation of the cabinet;

b) any required environmental conditions for cabinet installation and operation;

c) definition of all utilities required to operate the cabinet, including input power requirements and point of entries;

d) a description of the main component locations and functional description;

e) all operating procedures, description of the operating states, required operator actions, alarm and trip set points, and the related software and hardware user interfaces;

f) any servicing procedures and recommended spare parts;

g) definition of the applicable safety directives.

Supplier will provide the preliminary technical description with the proposal, which includes estimated weight and dimensions, utility and environmental requirements, software and hardware user interfaces and recommended spare parts.

49) See D.9 in Part 1.

Annex C
(informative)

Cross-section

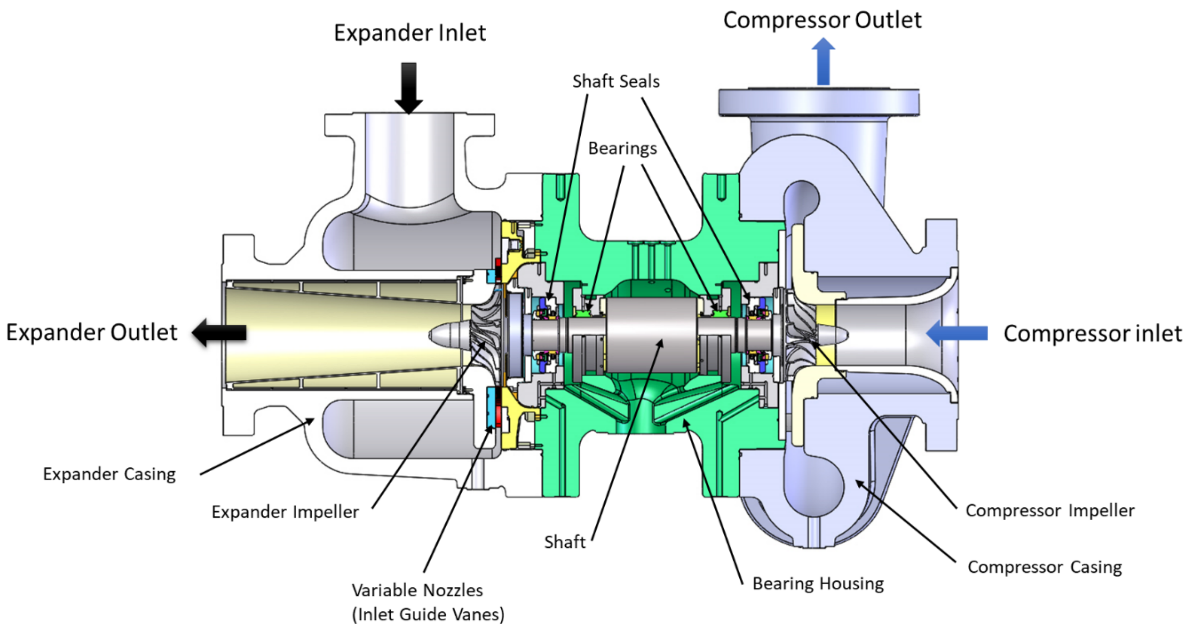

Figure C.1—Typical Expander-compressor Showing Key Parts

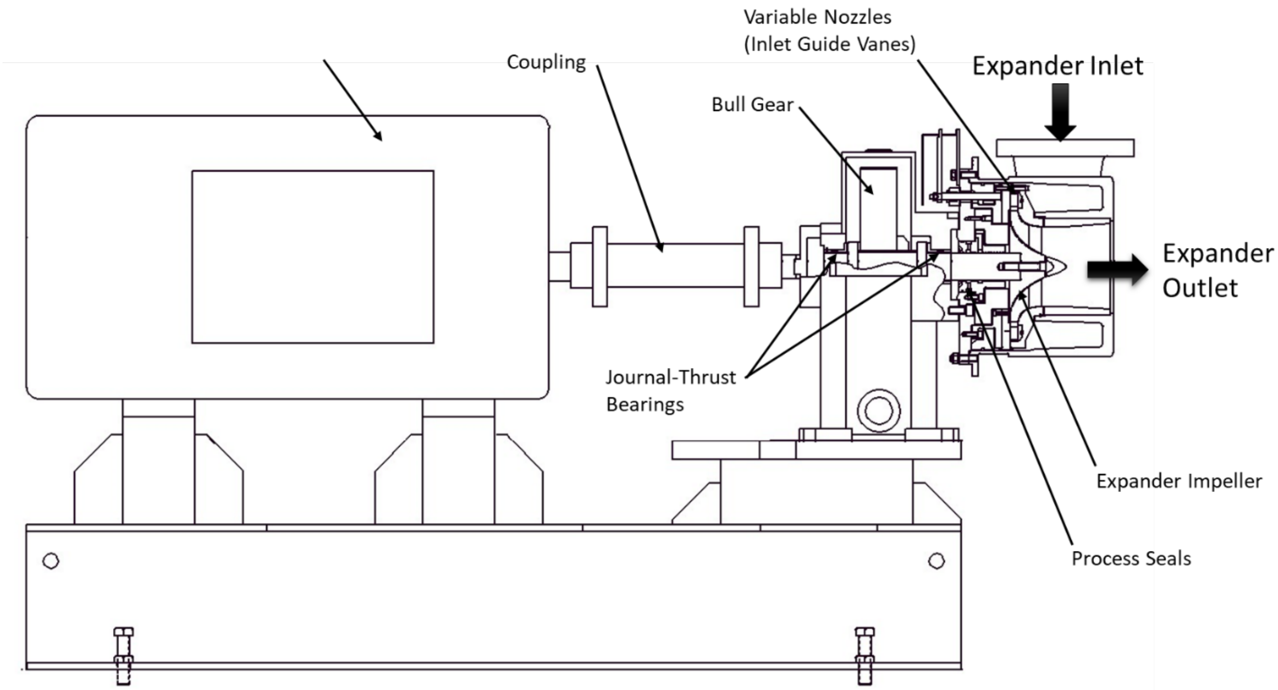

Figure C.2—Typical Expander-generator Showing Key Parts

Annex D
(normative)

Expander-generators

D.1 Scope

This annex covers the minimum requirements for expander-generators, in addition to the general requirements specified in Part 1 and Part 4. This scope covers integrally geared radial inflow expander-generators.

D.2 Normative References

Referenced documents indispensable for the application of this document are listed in Section 2 of Part 1.

D.3 Terms, Definitions, and Abbreviations

For the purposes of this document, the terms, definitions, and abbreviations given in Part 1 and Section 3 apply.

NOTE A cross section showing nomenclature of an expander-generator can be found in Annex C.

D.4 General

D.4.1 Dimensions and Units

The dimensional and unit requirements of Part 1 shall apply.

D.4.2 Statutory Requirements

The statutory requirements of Part 1 shall apply.

D.4.3 Unit Responsibility

The unit responsibilities of Part 1 shall apply.

D.4.4 Basic Design

D.4.4.1 The expander shall meet at least 98 % of the predicted efficiency at the certified point (see D.6.3.5.2).

D.4.4.2 Unless otherwise specified, the design lubricant shall be hydrocarbon oil of viscosity Grade 32 with an FZG load stage of 6, in accordance with ISO 8068. Viscosity Grade 46 with an FZG load stage of 6 may be used as a design lubricant, with purchaser's approval. Oils with extreme pressure additives shall not be used.

NOTE Typical oil used in refineries and chemical plants has an FZG of 5 or higher. Requiring a higher FZG by design can require the need for special oil for this equipment.

D.4.5 Materials

D.4.5.1 Materials shall be in accordance with 6.2 of Part 1. Refer to Annex F of Part 1 for a table of typical materials.

D.4.5.2 If traces of mercury have been specified, aluminum impellers shall be treated by anodizing or other approved methods.

D.4.6 Casings

D.4.6.1 General

Casings shall be in accordance with 6.3 of Part 1 and the additional requirements as follows.

D.4.6.2 Pressure-containing Casings

D.4.6.2.1 The MAWP of the expander casing(s) shall be at least equal to the relief valve set pressure(s) specified by the purchaser.

D.4.6.2.1.1 If a relief valve set pressure is not specified, the MAWP of the expander casing(s) shall be at least 1.1 times the maximum specified inlet pressure (gauge). System pressure protection shall be furnished by the purchaser.

D.4.6.2.1.2 When the purchaser has not supplied a relief valve setting, they shall be responsible for ensuring that casing pressure will not exceed casing MAWP ratings as set by D.4.6.2.1.

D.4.6.2.2 O-rings, gaskets, or other sealing devices that may be used on radially spilt casings shall be confined in machined grooves and shall be made of materials suitable for all specified service conditions.

D.4.6.2.3 The expander casing(s) shall be designed with sufficient strength to contain parts that might separate in the event of uncontrolled overspeed.

D.4.6.2.4 Socket-head or spanner-type bolting shall not be used externally unless specifically approved by the purchaser. For limited space locations, integrally flanged fasteners may be required.

D.4.6.3 Casing Repairs

Casing repairs shall be in accordance with 6.3.2 of Part 1.

D.4.6.4 Material Inspection of Pressure-containing Parts

Material inspection of pressure-containing parts shall be in accordance with 8.2.2 of Part 1.

D.4.6.5 Pressure Casing Connections

D.4.6.5.1 General

In addition to the requirements of 6.4 of Part 1, the following sections in D.4.6.5 shall apply.

D.4.6.5.2 Main Process Connections

Main process connections shall be in accordance with 6.4.2 of Part 1.

D.4.6.5.3 Auxiliary Connections

D.4.6.5.3.1 If flanged or machined and studded openings are impractical, threaded connections may be used where they do not come in contact with flammable or toxic gas, with purchaser’s approval as follows:

a) on nonweldable materials, such as cast iron;

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

These threaded openings shall be as specified in 6.4.4 of Part 1.

D.4.6.5.3.2 Auxiliary connections shall be at least DN 20 (NPS $^{3}/_{4}$ in.). See 6.9.2.10.3 through 6.9.2.12 of Part 3 and Table 1 of Part 3 for auxiliary gearbox connections.

NOTE See 6.4.1.4 and 6.4.1.5 of Part 1 for allowable connection sizes.

D.4.6.5.3.3 Threaded connections for pipe sizes DN 20 (NPS $^{3}/_{4}$ in.) through DN 40 (NPS 1 $^{1}/_{2}$ in.) size are permissible with the approval of the purchaser.

NOTE See 6.4.1.4 and 6.4.1.5 of Part 1 for allowable connection sizes.

D.4.6.6 Casing Support Structures

D.4.6.6.1 The mounting of the pressure casing to the gearbox shall be per 6.5.1 of Part 1. Bolting used to mount pressure casings shall be per 6.3.1.2 of Part 1.

D.4.6.6.2 The expander casing support structure shall be designed to mitigate loadings that are imposed due to thermal displacement to allow proper equipment operation during all expected conditions of operation.

NOTE Expanders normally utilize centerline mounting to minimize thermal mismatches that can adversely affect impeller running clearances, gear contact pattern, seals, bearings, and coupling alignment.

D.4.6.6.3 Pressure casing and supports shall be designed to have sufficient strength and rigidity to avoid adversely affecting impeller running clearances, gear contact pattern, seals, bearings, and coupling alignment.

D.4.6.7 External Forces and Moments

The supplier shall furnish the allowable forces and moments for each main process nozzle that has a customer connection in tabular form with the proposal.

NOTE Forces and moments allowed on integrally geared expanders are generally less than allowed for expander-compressors (see Annex F).

D.4.6.8 Variable Nozzles and Heat Shields

D.4.6.8.1 Refer to 6.5.3.

D.4.6.8.2 If required, an insulating heat shield shall be provided between the expander process side and the gearbox casing.

NOTE See Annex F of Part 1 for typical heat shield materials.

D.4.7 Rotating Elements

D.4.7.1 General

Rotating elements shall be in accordance with Part 4.

D.4.7.2 Thrust Balancing

A balance cavity, line, and porting can be provided if required to limit axial loads on the pinion.

D.4.8 Dynamics

D.4.8.1 Dynamics shall be in accordance with 6.8 of Part 1.

D.4.8.2 A lateral analysis shall be carried out for each shaft.

D.4.9 Bearings and Bearing Housings

D.4.9.1 General

D.4.9.1.1 Bearing and bearing housing requirements shall be in accordance with 6.7.4 of Part 1 and the following sections.

D.4.9.1.2 Unless otherwise specified, radial and thrust bearings shall be of the hydrodynamic fluid film type.

D.4.9.1.3 Unless otherwise specified, thrust bearings and radial bearings shall be fitted with bearing metal temperature sensors installed in accordance with API 670.

D.4.9.1.3.1 Unless otherwise agreed by purchaser and vendor, the predicted bearing metal temperature at maximum operating thrust load and rated speed shall be a maximum of 95 °C (200 °F), with a maximum inlet oil temperature of 50 °C (120 °F) and with the specified nominal lube oil inlet pressure. When the above criteria cannot be met, the purchaser and the vendor shall agree on acceptable bearing metal temperatures.

D.4.9.1.3.2 The gear manufacturer shall provide, in the test procedure, the predicted bearing metal temperature at the mechanical run test conditions. If the measured bearing metal temperature during the mechanical run test at the gear manufacturer's test stand exceeds this predicted temperature, the purchaser and the vendor shall agree on requirements for any additional testing and on the gear unit's suitability for shipment.

NOTE Mechanical run tests at the gear vendor's shop are typically conducted at no-load or low-load conditions. The bearing metal temperature during these tests will typically be less than the predicted temperature at rated load and rated speed.

D.4.9.2 Hydrodynamic Radial Bearings

D.4.9.2.1 Sleeve or pad radial bearings shall be used and shall be split for ease of assembly. The use of nonsplit designs requires the purchaser's approval. The bearings shall be precision bored with steel, copper, cupro-nickel, or bronze backed babbitted liners, pads, or shells. The bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

D.4.9.2.2 Unless otherwise specified, the liners, pads, or shells shall be in axially split housings. The bearing design shall not require removal of the coupling hub to permit replacement of the bearing liners, pads, or shells unless approved by the purchaser.

D.4.9.2.3 The minimum predicted film thickness, for any operating condition shall not be less than 25 µm (0.001 in.).

NOTE 1 Normally, the bearing L/D is less than 1.0.

NOTE 2 Normally, the bearing loading does not exceed 40 bar (550 psi) on a projected-area basis.

D.4.9.2.4 Hydrodynamic radial bearings shall conform to 6.7.2 of Part 3.

D.4.9.3 Hydrodynamic Thrust Bearings

D.4.9.3.1 Thrust loads from the impeller and gear shall be absorbed by the thrust bearing on pinion or transmitted to the bull gear thrust bearing by means of thrust rider rings fixed to the pinion and bull gear. All specified operating conditions and start-up conditions shall be evaluated for residual thrust loads.

D.4.9.3.2 Thrust bearings shall be used on pinions with dry gas seals. Use of thrust collars on pinions with dry gas seals require purchaser's approval.

NOTE Dry gas seals are prone to premature failure in the presence of excessive axial motions and vibrations. Refer to 7.4.7.1 and 7.4.7.2 of Part 3 for axial displacement and vibration monitoring.

D.4.9.3.3 Hydrodynamic thrust bearings shall be fix geometry or tilt pad design.

D.4.9.3.4 Loads on hydrodynamic thrust bearings shall be limited to no more than 50 % of the bearing manufacturer's ultimate load rating at specified operating conditions.

NOTE Loading of 50 % of the ultimate load can be exceeded during start-up or upset conditions. However, at no conditions, loads on hydrodynamic thrust bearings shall exceed the bearing manufacturer's maximum continuous rating.

D.4.9.3.5 Hydrodynamic bearings shall conform to 6.7.2 of Part 3.

D.4.9.4 Bearing Housings

The term "bearing housing" refers to all bearing enclosures including the gearbox.

D.4.10 Expander-generator Shaft End Seals

D.4.10.1 Process seals and seal systems shall be in accordance with 6.9.1 of Part 1.

D.4.10.2 Shaft end seals shall be provided to prevent the leakage of process gas into the gearbox over the range of specified operating conditions, including start-up, shutdown, or settle out.

D.4.10.3 [●] The purchaser shall specify the type of shaft end seal(s) to be provided.

D.4.11 Integral Gearing

Integral gearing shall be in accordance with 6.9.2 of Part 3.

D.4.12 Nameplates and Rotation Arrows

Nameplates and rotation arrows shall be in accordance with 6.9.3 of Part 1 and 6.9.5 of Part 3.

D.5 Accessories

D.5.1 General

Accessories shall conform to Section 7 of Part 1 and Part 3.

D.5.2 Generators

NOTE Expander-generator units do not have separate drivers.

D.5.2.1 [●] The generator shall be of the type specified, sized to meet the maximum specified operating conditions, and shall be in accordance with applicable specifications.

D.5.2.2 Low-voltage induction generators shall be in accordance with IEEE 841 (up to 370 kW [500 hp]).

D.5.2.3 Medium-voltage induction generators shall be in accordance with API 541 [186 kW (250 hp) and larger].

D.5.2.4 Medium-voltage synchronous generators shall be in accordance with API 546 (500 kVA and larger).

D.5.2.5 The generator shall operate at rated power (or MVA), frequency and terminal voltage as well as site conditions specified.

D.5.2.6 The generator shall be sized to accept any specified process variations such as changes in the pressure, temperature, or properties of the fluids handled and plant start-up conditions.

D.5.3 Couplings and Guards

Couplings and guards shall conform to 7.5 of Part 1.

D.5.4 Lubrication and Sealing Systems

Lubrication and sealing systems shall conform to 7.1 of Part 1.

D.5.5 Baseplates and Soleplates

Baseplates and soleplates shall conform to 7.2.1 of Part 1.

D.5.6 Controls and Instrumentation

D.5.6.1 General

Controls and instrumentation shall be in accordance with 7.3.2, 7.3.3, and 7.3.4 of Part 1 and the following in this section.

D.5.6.2 Vibration and Position Monitoring

Vibration and position monitoring shall conform to 7.3.7 of Part 3.

D.5.6.3 Control Systems

D.5.6.3.1 An adjustable inlet guide vane mechanism shall be furnished by the supplier as an integral part of the expander.

D.5.6.3.2 For adjustable inlet guide vanes, the supplier shall furnish a guide vane positioner compatible with the type of control signal specified by the purchaser.

D.5.6.3.3 [●] If specified, the guide vane positioner shall include a local manual override for induction-type generators. A direct-driven vane position indicator shall be provided that will be visible during operation of the machine.

D.5.6.3.4 Start-up

D.5.6.3.4.1 If the turboexpander-generator is to be started unloaded and the generator brought online as the expander is brought to speed, the supplier shall design the synchronization control system to energize the generator to provide synchronization and avoid an overspeed event as well as avoiding operation at critical speeds.

NOTE This method applies to both synchronous and induction-type generators.

D.5.6.3.4.2 If the turboexpander-generator is to be started with the generator acting as a motor, the supplier shall design the control system to prevent equipment damage while the expander is in motoring mode and to transition to generating mode smoothly.

NOTE This method is primarily used for induction-type generators.

D.5.6.3.5 Shutdown Logic Sequence

D.5.6.3.5.1 The vendor shall provide the shutdown logic sequence.

D.5.6.3.5.2 In order to prevent a hazardous overspeed condition, the shutdown logic sequence for a generator loaded expander shall be designed to remove expander motive power (close the inlet trip valve) prior to removing the generator load (disconnecting generator from the grid).

D.5.6.4 Overspeed Shutdown System

D.5.6.4.1 General

D.5.6.4.1.1 General requirements for overspeed shutdown system shall conform to 7.8.3 and the following in this section.

D.5.6.4.1.2 The supplier shall design an overspeed shutdown system consisting of:

a) electronic overspeed circuit [speed sensor(s) and logic device];

b) expander inlet trip valve equipped with solenoid valves.

D.5.6.4.1.3 An overspeed shutdown system based on two-out-of-three voting logic shall be furnished.

NOTE Overspeed primarily results from an interruption of load from the generator, or during start-up. The design of the generator electrical system, including switchgear and associated controls, ensures that generator load interruption does not occur. Since an overspeed condition in a turboexpander-generator can have more significant impact than a turboexpander-compressor, redundant overspeed detection and trip systems are the standard.

D.5.6.4.1.4 The control system shall detail electrical protection, which will be implemented on the switch gear to prevent loss of connection to the grid while the generator is loaded.

NOTE The loss of connection to the grid will likely cause an overspeed event. It can be avoided by proper electrical protection, which will trip the expander-generator before loss of connection.

D.5.6.4.1.5 The control system shall be designed to ensure the electrical load will not be removed before complete closure of trip valve.

NOTE This is not always possible for actions initiated by electrical faults.

D.5.6.4.2 Electronic Overspeed Detection System

D.5.6.4.2.1 An electronic overspeed detection system per API 670, consisting of three independent speed sensors and logic devices, shall be furnished. The design of the system shall include the following.

a) All settings incorporated in the overspeed system shall be protected through controlled access.

b) It shall accept inputs from a frequency generator for verifying the trip speed setting.

c) It shall provide an output for a speed indicator and start-up synchronization speed control.

NOTE When unexpected loss of load is frequent or consequences of overspeed is significant, redundant inlet trip valves can be considered.

D.5.6.4.2.2 The two out of three configuration for the electronic overspeed detection circuit shall have the following characteristics.

a) An overspeed condition sensed by any one circuit shall initiate an alarm.

b) An overspeed condition sensed by two out of three circuits shall initiate a trip.

c) Failure of a speed sensor, power supply, or logic device in any circuit shall initiate an alarm only and cause the logic to revert to a 1 out of 2 voting arrangement.

d) Failure of two or more circuits shall initiate a trip.

e) If speed indication is utilized for start-up control and generator synchronization, the speed shall be measured on the high-speed pinion or gear mesh to ensure adequate speed signal resolution.

D.5.6.4.2.3 Speed sensing shall be performed in accordance with API 670—Section 5.

D.5.6.4.3 Expander Trip Valve

D.5.6.4.3.1 Expander trip valve shall conform to 7.8.4 and the following in this section.

D.5.6.4.3.2 The expander inlet trip valve(s) shall be able to close within an agreed upon time not to exceed 500 milliseconds; the timing requirement of the trip valve(s) shall include consideration of an expander overspeed analysis and speed of response of the control system.

NOTE A loss of load on an expander-generator can result in rapid acceleration leading to a hazardous overspeed condition. The trip valve timing prevents excessive expander overspeed in the event of a loss of load.

D.5.6.4.3.3 The transient response analysis shall be performed to determine the required speed of response for the logic and trip valve as required by D.5.6.4.3.3.1 and D.5.6.4.3.3.3.

D.5.6.4.3.3.1 The purchaser will provide the piping layout and system volume downstream of the trip valve(s) required for the vendor to perform transient response analysis.

D.5.6.4.3.3.2 The transient response analysis shall be performed at the generator nameplate rating with a complete and instantaneous loss of generator load.

D.5.6.4.3.3.3 The dead times of the overspeed trip logic solver and solenoids shall be included when calculating the required closing time.

NOTE The acceleration characteristics of expander-generators on an instantaneous loss of load can vary significantly based on gear ratio, available expander power (e.g. process conditions, piping layout, and off-design performance of the expander) and equipment train inertias.

D.5.6.4.3.4 The transient response analysis shall validate the ability of overspeed trip system to prevent damage to any component of the expander-generator train.

D.5.6.4.3.5 Electric Solenoid Valves

Electric solenoid valves shall conform to 7.8.5.

D.5.7 Piping and Appurtenances

Piping and appurtenances shall conform to 7.8.6.

D.5.8 Special Tools

Special tools shall be furnished in accordance with 7.4 of Part 1.

D.6 Inspection, Testing, and Preparation for Shipment

D.6.1 General

D.6.1.1 Inspection, testing, and preparation for shipment shall be in accordance with Section 8 except as modified below.

D.6.1.2 General requirements for inspection, testing, and preparation for shipment shall be in accordance with 8.1 of Part 1. Also refer to Annex E for the Inspector's Checklist.

D.6.2 Inspection

Requirements for inspection shall be in accordance with 8.2 of Part 1.

D.6.3 Testing

D.6.3.1 General

Testing shall conform to requirements of 8.4.

NOTE Paragraphs referring to magnetic bearings and compressors are not applicable.

Gear contact checks shall conform to requirements of 8.2.2 of Part 3.

D.6.3.2 Impeller Modal Test

Testing shall conform to requirements of 8.4.2.

D.6.3.3 Mechanical Running Test

D.6.3.3.1 Mechanical running test shall conform to requirements of 8.3.2 of Part 3 except as modified below.

D.6.3.3.2 The contract shaft seals shall be used in the machine for the mechanical running test.

NOTE Test expander seals can be required due to the temperature differences between operating conditions and test conditions.

D.6.3.3.3 The vendor proposal shall clarify the use of any device to absorb the power generated in the mechanical running test.

NOTE The expander and gear assembly is commonly tested uncoupled from any generator for the mechanical run test. The losses in the bearings and gearing of the expander and gear assembly are generally sufficient to allow proper control of the expander speed on the test stand.

D.6.3.3.4 The expander stage shall be utilized as the driver during the mechanical running testing.

NOTE This helps ensure that the same gear flanks are loaded as in normal operation and general loading characteristics for the gearing and bearings are in the same relative direction as normal operation.

D.6.3.3.5 [●] If specified, a job-coupling half-moment simulator shall be used for the mechanical running test.

D.6.3.3.6 The expander-generator shall be dismantled, inspected, and retested, if any unacceptable vibration is detected during the mechanical running test.

D.6.3.4 Assembled Machine Gas Leakage Test

Assembled machine gas leakage test shall conform to requirements of 8.4.4.

D.6.3.5 Optional Tests

D.6.3.5.1 General

Refer to 8.3.7 of Part 1 for optional tests.

D.6.3.5.2 Performance Test

Performance test shall conform to requirements of 8.4.5.2 with the expander as the primary objective.

D.6.3.5.3 Complete Unit Test

D.6.3.5.3.1 Complete unit test shall conform to requirements of 8.3.4.3 of Part 3 and the following paragraphs.

D.6.3.5.3.2 All components including the expander, gear, generator, and auxiliaries that make up a complete unit shall be tested together. The complete unit test can be performed in place of, or in addition to, the mechanical running test of the expander.

NOTE A complete unit test for an expander-generator requires significant coordination efforts to stage and assemble the various components into the equipment train for the test. The global differences in electrical voltages and frequencies and the ability to recover generated power, while operating on the test stand needs to be addressed.

D.6.3.5.3.3 [●] If specified, for the complete unit test, torsional vibration measurements shall be made to verify the supplier's analysis.

D.6.4 Preparation for Shipment

Preparation for shipment shall be in accordance with 8.5.

D.7 Supplier's Data

D.7.1 General

Supplier data shall be provided in accordance with Section 9.

D.7.2 Proposals and Technical Data

Technical data shall be in accordance with 9.2.2.

D.7.3 Contract Data

Contract data shall be in accordance with 9.3.

Annex E
(informative)

Inspector's Checklist

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
6.2 MATERIALS					
Coating applied prior to acceptance balance	6.2.2.1	1			
PMI	6.2.3.1	1			
Impact testing	6.2.4.3	1			
Castings—material specification compliance	6.2.5.1	1			
Castings—purchaser approval of repairs	6.2.5.5.4	1			
Castings—ductile (nodular) iron	6.2.5.7	1			
Forgings—repairs	6.2.6.2	1			
Welding—nonpressure components	6.2.7.1	1			
Welding—pressure-containing and rotating parts	6.2.7.2	1			
6.3 CASINGS					
Jackscrews, dowels, and special tools	6.3.1.5	1			
Provisions for lifting casings	6.3.2.3	4			
Depth of threaded holes	6.3.1.6.2	1			
Studs instead of cap screws	6.3.1.8.3	1			
Adequate clearance at bolts	6.3.1.8.4	1			
Bolting materials	6.3.1.8.8	1			
Welding	6.3.1.9	1			
Casing repair—minimum level of inspection and purchaser review	6.3.2.1	1			
Casing repair—major repairs	6.3.2.4.1	1			
Casing repair—material standards	6.3.2.5	1			

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Pressure casings—plate edges	6.3.2.6.1	1			
Pressure casings—MPT or LPT	6.3.2.6.2	1			
Pressure casings—weld QC	6.3.2.6.3	1			
Pressure casings—full penetration welds	6.3.2.6.4	1			
Casings—heat treatment	6.3.2.6.5	1			
Pressure-containing weld inspection	6.3.2.6.6	1			
Materials inspection standards	6.3.3.3	1			
Cast steel casings—acceptability of defects	6.3.3.4	1			
Pressure casing connection size	6.4.1.4	1			
Casing connections—welding before hydro test	6.4.1.7	1			
Main process connection orientation	6.4.2.1	1			
Flanges	6.4.2.2	1			
Cast iron flanges	6.4.2.9	1			
Concentricity of bolt circle and bore	6.4.2.13	1			
Steel flange facing finish	6.4.2.14	1			
Machined and studded connections	6.4.2.15	1			
Flanges parallel within 0.5 degrees	6.4.2.17	1			
Auxiliary connections—minimum size	6.4.2	4			
Auxiliary connections—flanges	6.4.3.2	1			
Auxiliary connections—allowable types	6.4.3.3	1			
Auxiliary connections—pipe nipples	6.4.3.6	1			
Auxiliary connections—socket weld gap	6.4.3.7	1			
Auxiliary connections—lube or seal service	6.4.3.4	1			
Threaded openings for tapered pipe threads	6.4.4.1	1			
Tapered pipe threads	6.4.4.2	1			
Seal welding tapered pipe threads	6.4.4.3	1			

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Pipe nipples for threaded openings	6.4.4.4	1			
Plugs for threaded openings	6.4.4.5	1			
Machine mounting surfaces	6.5.1	1			
6.6 ROTATING ELEMENTS					
Shaft ends for couplings	6.6.1.1	1			
Impeller and shaft marking	6.6.1.2	4			
Shaft sensing areas for probes	6.6.1.2	1			
Shaft sensing areas—final surface finish	6.6.1.3	1			
Shaft weld NDE	6.6.3	4			
Coating or overlay to prevent wire wooling	6.6.3	4			
Thrust collar surface finish and TIR	6.6.1.6	1			
Fabricated impeller inspection	6.6.2.3	1			
Cast impeller inspection	6.6.2.4	1			
Cast impeller repair	6.6.2.5	1			
Welding not permitted for impeller balancing	6.6.2.6	1			
MPT or LPT of impellers after overspeed	6.6.2.7	1			
6.8 DYNAMICS					
Confirmation of critical speeds	6.8.3.1.9	1			
Unbalanced rotor response verification test	6.8.3	1			
Additional testing	6.8.3.2	1			
Balancing method for single-shaft expander-compressors	6.8.2.1	4			
Rotating element—component balance	6.8.7.1	1			
Rotating element—sequential multiplane balance	6.8.7.6	1			
Rotating element—if disassembled after balance	6.8.7.7	1			

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Rotating element—assembly and balance verification	6.8.2.6	4			
Rotating element—reassembly check balance	6.8.7.7	1			
Rotating element—residual unbalance check	6.8.2.7.1	4			
Operating speed balance	6.8.7.8	1			
Operating speed balance procedure	6.8.8	1			
6.9.2 NAMEPLATES AND ROTATION ARROWS					
Nameplate at readily visible location	6.9.3.1	1			
Nameplate material	6.9.3.2	1			
Nameplate contents	6.9.2.2	4			
Rotation arrows	6.9.2.1	4			
Lateral critical speeds on nameplate	6.9.3.6	1			
7.2.1 BASEPLATES AND SOLEPLATES					
Jackscrews	7.2.1.2.1 7.2	1 4			
Alignment shims	7.2.1.2.2	1			
Machinery mounting surfaces	7.2.1.2.3	1			
Anchor bolt clearance	7.2.1.2.8	1			
Vertical leveling screws	7.2.1.2.9	1			
Radiused corners for grout	7.2.1.2.10	1			
Hold-down bolt clearance	7.2.1.2.13	1			
Wrench clearance	7.2.1.2.13	1			
Grout contacting surface preparation	7.2.1.2.16	1			
Mounting surface preservation	7.2.1.2.18	1			
Seal welded joints	7.2.2.3	1			
Leveling pads or targets	7.2.2.8	1			

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Additional pads or targets	7.2.2.8.2	1			
Lifting lugs	7.2.2.9.1	1			
Grout fill and vent holes	7.2.2.10.1	1			
Soleplate thickness	7.2.3.2	1			
Soleplate size	7.2.3.3	1			
Soleplates fully machined	7.2.3.5	1			
Subsoleplates	7.2.3.6	1			
7.3 CONTROLS AND INSTRUMENTATION					
Controls ingress protection level	7.3.1.4	1			
Terminal box ingress protection level	7.3.1.5	1			
Conduit and cable location and installation	7.3.1.6	1			
Transducers per API 670	7.3.2.1	4			
Axial probes per API 670	7.3.2.2	4			
Monitors per API 670	7.3.2.3	4			
Radial bearing temperature sensors per API 670	7.8.1.1	4			
Thrust bearing temperature sensors per API 670	7.8.1.2	4			
Bearing temperature monitor per API 670	7.8.1.3	4			
Magnetic bearing temperature sensors	7.8.2	4			
Overspeed shutdown system per API 670	7.8.3	4			
7.4 SPECIAL TOOLS					
Use of tools	7.4.3	1			
Tool packing and marking	7.4.4	1			
7.8.6 PIPING AND APPURTENANCES					
Breakout spools	7.8.1.1.3	1			
Provisions to bypass bearings	7.8.1.1.4	1			
Provisions to bypass dry gas seals	7.8.1.1.5	1			

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Instrument piping	7.8.1.2	1			
Process piping	7.8.1.3	1			
Piping terminate at skid edge	7.8.6.3	4			
8.1 INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT—GENERAL					
Access to vendor's quality control program	8.1.8	1			
8.3 INSPECTION					
Painting before hydro test	8.2.1.2	1			
Cleanliness	8.2.1.5	1			
Hardness of parts, welds, and heat-affected zones	8.2.1.7	1			
Radiographic inspection	8.2.3	1			
Ultrasonic inspection	8.2.4	1			
Magnetic particle inspection	8.2.5	1			
Liquid penetrant inspection	8.2.6	1			
8.4 TESTING					
Contact probes and accelerometers used	8.3.5.1	1			
Contract shaft seals and bearings used	8.4.3.1.1	4			
Oil system cleanliness before testing	8.4.3.1.5	4			
Joint and connection tightness	8.3.5.6	1			
Warning, protective, and control devices	8.3.5.7	1			
Hydrostatic test—pressure	8.3.2.1	1			
Hydrostatic test—duration	8.3.2.3	1			
Hydrostatic test—chloride content	8.3.2.4	1			
Impeller overspeed test	8.3.3	1			
Residual magnetism	8.3.5	1			
Dry gas seals	8.3.4	1			

Item (Inspector Checklist Part 4)	**Standard 617**		**Date Inspected**	**Inspected by**	**Status**
	Section	**Part**			
Mechanical running test—operation of equipment and test instrumentation	8.3.5.10.1	1			
Mechanical running test—unfiltered vibration	8.3.5.10.2	1			
Mechanical running test—vibration plots	8.3.5.10.3	1			
Mechanical running test—real-time vibration data recorded	8.3.5.10.5	1			
Mechanical running test—seal flow data	8.3.5.10.6	1			
Mechanical running test—lube oil and seal oil variations	8.3.5.10.7	1			
Mechanical running test—hydrodynamic bearing inspection	8.3.5.11.1 8.4.3.4.1	1 4			
Mechanical running test—shaft end seal inspection	8.3.5.12 8.4.3.4.2	1 4			
Spare mechanical center sections tested	8.4.3.3.7	4			
Gas test after hydro	8.3.7.3	1			
Assembled compressor gas leak test	8.4.4.1	4			
Sound-level test	8.3.7.4	1			
Auxiliary-equipment test	8.3.7.5	1			
Post-test inspection of internals	8.3.7.6	1			
Full-load/full-pressure/full-speed test	8.3.7.7	1			
Post-test inspection of coupling fit	8.3.7.8	1			
Spare-parts test	8.3.7.9	1			
8.5 PREPARATION FOR SHIPMENT					
Preparation for shipment	8.4.1	1			
Spare center section prepared for storage	8.5.2	4			
Testing completed and equipment released	8.4.3	1			
Coating on exterior surfaces	8.4.3.1.1	1			

Item (Inspector Checklist Part 4)	Standard 617		Date Inspected	Inspected by	Status
	Section	Part			
Exterior machined surfaces coating	8.4.3.2	1			
Interior of equipment	8.4.3.3	1			
Internal surfaces of bearing housings	8.4.3.5	1			
Flange covers	8.4.3.6	1			
Threaded openings	8.4.3.7	1			
Beveled welding openings	8.4.3.8	1			
Lifting point identification	8.4.3.9	1			
Equipment tagging and packing lists	8.4.3.11	1			
Spare rotor storage preparation	8.4.3.12	1			
Spare rotor container	8.4.3.12.3	1			
Cradle support liner	8.4.3.13	1			
Rotor preparation for vertical storage	8.4.3.12.4	1			
Fit-up and assembly of piping and heat exchangers	8.4.3.14	1			
Shaft and coupling protection	8.4.3.15	1			
Auxiliary connection marking	8.4.4	1			
Auxiliary piping match marks	8.4.6	1			
IOM shipped with equipment	8.4.7	1			
Wood used in export shipping	8.4.8	1			

Annex F
(informative)

Nozzle Forces and Moments

F.1 General

The April 1988, November 1979, and October 1973 issues of this standard referred nozzle forces and moments calculations to appropriate NEMA documents, with the stipulation that the constants in the equations be multiplied by 1.85. Experience has shown that there has not been a uniform interpretation of "1.85 times NEMA"; therefore, the equations have been adapted to expander-compressors by identifying all the constants and clarifying that the equivalent of the exhaust nozzle in the NEMA calculation is the largest expander or compressor nozzle. This is usually, but not necessarily, the outlet nozzle.

F.2 Equations

The design of each expander-compressor body shall allow for limited piping loads on the various casing nozzles. For maximum system reliability, nozzle loads imposed by piping should be as low as possible regardless of the expander-compressor load-carrying capability. For single-stage expander-compressors, the forces and moments acting on expander or compressor due to the inlet and discharge connections should be limited by the following.

The total resultant force and total resultant moment imposed on the compressor at any connection should not exceed the values shown in Equation (F.1).

In SI units:

$$F_{\mathrm{r}} + 1.09 M_{\mathrm{r}} \leq 54.1 D_{\mathrm{e}} \quad \text{(F.1a)}$$

In USC units:

$$3F_{\mathrm{r}} + M_{\mathrm{r}} \leq 927 D_{\mathrm{e}} \quad \text{(F.1b)}$$

where

F_{r} is the resultant force, in newtons (lb) (see Figure F.1);

M_{r} is the resultant moment, in newton-meters (ft-lb) from Figure F.1.

$$M_{\mathrm{t}} = \sqrt{M_{\mathrm{z}} + M_{\mathrm{y}} + M_{\mathrm{z}}} \quad \text{(F.2)}$$

For sizes up to 200 mm (8 in.) in diameter:

D_e is equivalent pipe diameter of the connection, mm (in.).

For sizes greater than 200 mm (8 in.), use the following values.

In SI units:

$$D_e = \frac{(400 + D_{nom})}{3} \text{ (mm)} \tag{F.3a}$$

In USC units:

$$D_e = \frac{(16 + D_{nom})}{3} \text{ (in.)} \tag{F.3b}$$

where

D_e is the equivalent pipe diameter of the connection, mm (in.);

D_{nom} is the nominal pipe diameter, mm (in.).

The combined resultants of the forces and moments of the inlet, side stream, and discharge connections resolved at the centerlines of the largest connection should not exceed the following.

The resultants shall not exceed the following.

In SI units:

$$F_c + 1.64 M_c \leq 40.4 D_c \tag{F.4a}$$

In USC units:

$$2F_c + M_c \leq 462 D_c \tag{F.4b}$$

where

F_c is the combined resultant of inlet, side stream, and discharge forces, newtons (lb);

M_c is the combined resultant of inlet, side stream, and discharge moments, and moments resulting from forces, newton-meters (ft-lb);

D_c is the diameter [mm (in.)] of one circular opening equal to the total areas of the inlet, side stream, and discharge openings; if the equivalent nozzle diameter is greater than 230 mm (9 in.), use a value of D_c equal to the following.

In SI units:

$$D_c \frac{(460 + \text{Equivalent Diameter})}{3} \text{ (mm)} \tag{F.5a}$$

In USC units:

$$D_c \frac{(18 + \text{Equivalent Diameter})}{3} \text{ (in.)} \tag{F.5b}$$

The individual components (see Figure F.1) of these resultants should not exceed the following.

In SI units:

$F_x = 16.1D_c \quad M_x = 24.6D_c$

$F_y = 40.5D_c \quad M_y = 12.3D_c$

$F_z = 32.4D_c \quad M_z = 12.3D_c$

In USC units:

$F_x = 92D_c \quad M_x = 462D_c$

$F_y = 231D_c \quad M_y = 231D_c$

$F_z = 185D_c \quad M_z = 231D_c$

where

F_x is the horizontal component of F_c, parallel to the compressor shaft, newtons (lb);

F_y is the vertical component of F_c, newtons (lb);

F_z is the horizontal component of F_c at right angles to be compressor shaft, newtons (lb);

M_x is the component of M_c, around the horizontal axis, newton-meters (ft-lb);

M_y is the component of M_c, around the vertical axis, newton-meters (ft-lb);

M_z is the component of M_c around the horizontal axis at right angles to the compressor shaft, newton-meters (ft-lb).

These values of allowable forces and moments pertain to the turbo-expander structure only. They do not pertain to the forces and moments in the connecting pipes, flanges, and flange bolting, which should not exceed the allowable stress as defined by applicable codes and regulatory bodies.

Loads can be increased by mutual agreement between the purchaser and the vendor; however, it is recommended that expected operating loads be minimized.

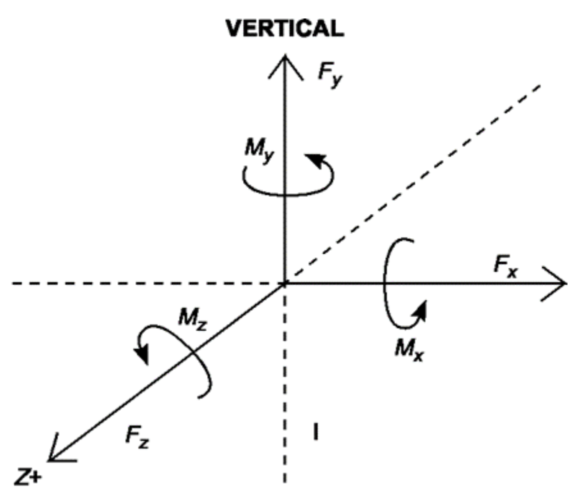

Figure F.1—Combined Resultants of the Forces and Moments of Corrections

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