Liquid Ring Vacuum Pumps and Compressors for Petroleum, Chemical, and Gas Industry Services

API STANDARD 681
FIRST EDITION, FEBRUARY 1996

American Petroleum Institute

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Manufacturing, Distribution and Marketing Department

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FOREWORD

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of the standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard rather than by rewriting or incorporating sections of this standard into another complete standard.

Suggested revisions are invited and should be submitted to the director of the Manufacturing, Distribution and Marketing Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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Liquid Ring Vacuum Pumps and Compressors for Petroleum, Chemical, and Gas Industry Services

SECTION 1—GENERAL

1.1 Scope

1.1.1 This standard covers the minimum requirements for liquid ring vacuum pump and compressor systems for service in the petroleum, chemical, and gas industries. This includes both vacuum pump and compressor design and system design.

1.1.2 The design of the system is critical to the successful operation of the liquid ring vacuum pump or compressor. Close attention must be paid not only to the design of the ring liquid system but also to how it is integrated into the user's process.

1.1.3 Although this standard covers minimum requirements appropriate for petroleum refinery service, purchasers may wish to consider pumps, compressors, and systems that do not meet all the requirements of this standard, based on specific nonflammable, nontoxic service conditions.

Note: A bullet (•) at the beginning of a paragraph indicates that a decision by the purchaser is required. These decisions should be indicated on the data sheet (see Appendix A); otherwise, they should be stated in the quotation request or in the order.

1.2 Alternative Designs

The vendor may offer alternative designs. Equivalent metric dimensions, fasteners, and flanges may be substituted as mutually agreed upon by the purchaser and the vendor.

1.3 Conflicting Requirements

In case of conflict between this standard and the inquiry, or order, the information included in the order shall govern.

1.4 Definition of Terms

Terms used in this standard are defined in 1.4.1 through 1.4.26 (refer to Figure 1).

1.4.1 The *alarm point* is a preset value of a parameter at which an alarm is actuated to warn of a condition that requires corrective action.

1.4.2 The *compressor rated point* is the point on the 100 percent speed curve at the highest capacity of any specified.

1.4.3 *Hydrodynamic bearings* are bearings that use the principles of hydrodynamic lubrication. Their surfaces are oriented so that relative motion forms an oil wedge to support the load without journal-to-bearing contact.

1.4.4 *Inlet cubic feet per minute* (ICFM) refers to the flow rate determined at the conditions of pressure, temperature, compressibility, and gas composition, including moisture, at the compressor inlet flange. *Actual cubic feet per minute* (ACFM) may be used to refer to flow at a number of locations and should therefore not be used interchangeably with inlet cubic feet per minute.

1.4.5 A *liquid ring vacuum pump, or compressor,* is a rotary positive-displacement machine in which gas compression is achieved by the action of a radially bladed impeller mounted in an eccentric or elliptical casing which is partially filled with liquid.

1.4.6 *Maximum allowable differential pressure* is the maximum differential pressure for which the manufacturer has designed the equipment for continuous operation.

1.4.7 *Maximum allowable speed* (revolutions per minute) is the highest speed at which the manufacturer's design will permit continuous operation.

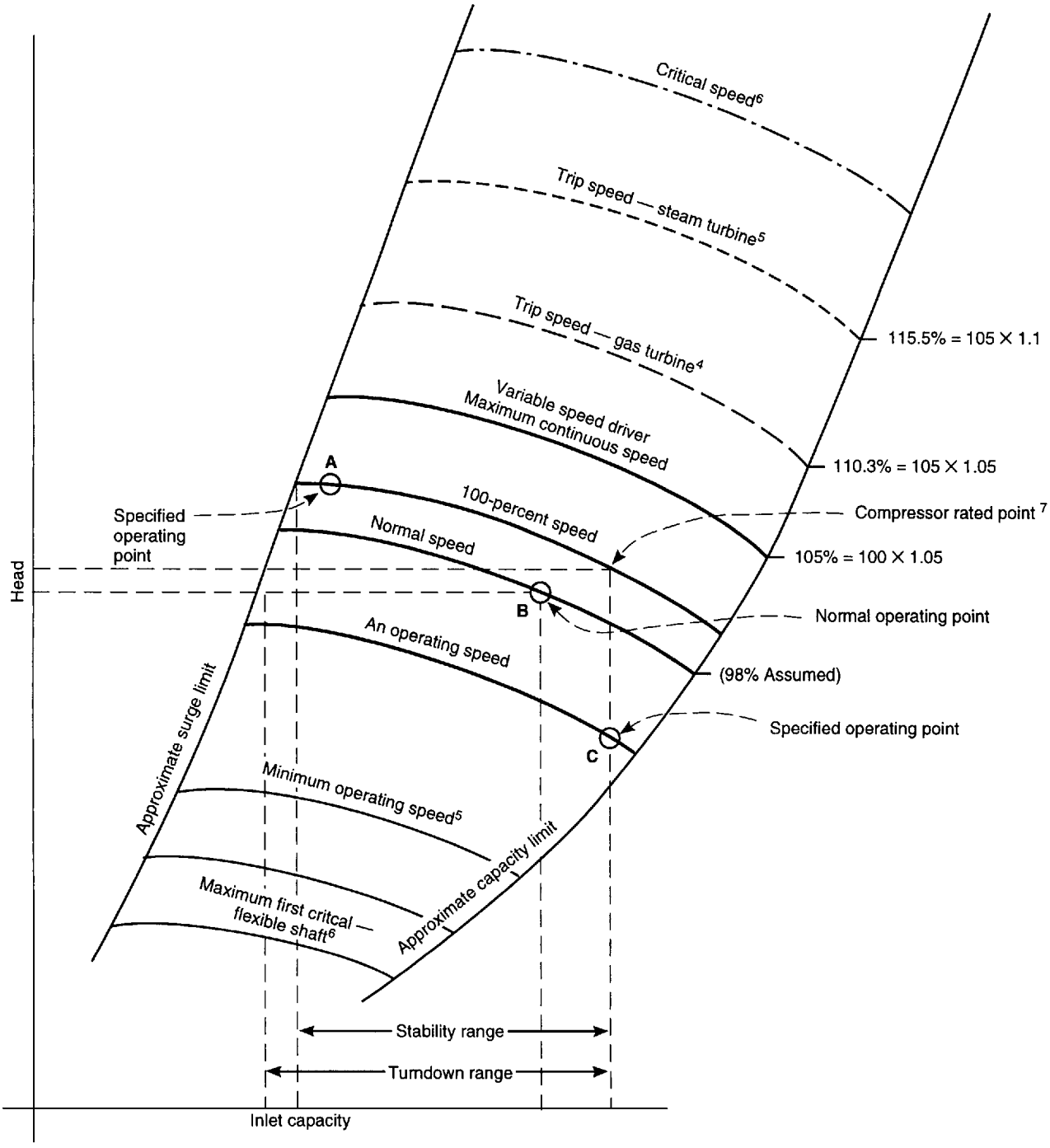
1.4.8 *Maximum allowable temperature* is the maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure.

1.4.9 *Maximum allowable vacuum* is the maximum vacuum (minimum suction pressure) for which the manufacturer has designed the equipment, corrected for the vapor pressure of the seal liquid at the operating temperature.

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

1.4.11 *Maximum continuous speed* (revolutions per minute) is the speed at least equal to 105 percent of the rated speed. Maximum continuous speed for constant-speed drivers shall be equal to the 100-percent speed.

1.4.12 *Maximum differential pressure* is the maximum discharge pressure minus the minimum suction pressure that the pump is able to develop when operating at the specified speed, specific gravity, and pumping temperature.



Notes:

1. Except where specific numerical relationships are stated, the relative values implied in this figure are assumed values for illustration only.
2. The 100 percent speed curve is determined from the operating point requiring the highest head; point A in the illustration.
3. The compressor rated point (CRP) is the intersection on the 100 percent speed line corresponding to the highest flow of any operating point; point C in the illustration.
4. The head-capacity curve at 100 percent speed shall extend to at least 115 percent of the capacity of the CRP. Head-capacity curves at other speeds shall be extended to equivalent capacity at each speed. For example, the head-capacity curve at 105 percent speed shall be extended to at least 1.05 times 1.15 times the capacity of the CRP; the head-capacity curve at 90 percent speed shall be extended to at least 0.9 times 1.15 times capacity of the CRP; and so on. These points define the "approximate capacity limit" curve.
5. Refer to the applicable standard for the compressor driver such as API Standard 612 (Steam Turbine) or API Standard 616 (Gas Turbine) for trip speed and minimum operating speed limits.
6. Refer to 2.7 for allowable margins of critical speeds to operating speeds.
7. See 1.4.4.

Figure 1—Illustration of Terms

1.4.13 *Maximum discharge pressure* is the maximum suction pressure plus the maximum differential pressure that the pump is able to develop when operating at the specified speed, specific gravity, and pumping temperature.

1.4.14 *Maximum sealing pressure* is the highest pressure expected at the seals during any specified static or operating condition and during start-up and shutdown.

1.4.15 *Minimum allowable temperature* is the minimum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred).

1.4.16 *Normal operating point* is the point at which usual operation is expected and optimum efficiency is desired.

1.4.17 The *casing* is the composite of all stationary pressure-containing parts of the unit, including all nozzles, seal glands, and other attached parts but excluding the stationary and rotating members of mechanical seals (see Figure E-1, Appendix E).

1.4.18 *Radially split* refers to casing joints that are transverse to the shaft centerline.

1.4.19 *Rated discharge pressure* is the highest pressure required to meet the conditions specified by the purchaser for the intended service.

1.4.20 The *rated operating point* is the point at which the vendor certifies that performance is within the tolerances stated in this standard. Performance includes the following factors: capacity, power, efficiency, rotative speed, and rated suction and discharge pressures.

1.4.21 The *shutdown point* is a preset value of a parameter at which automatic or manual shutdown of the system is required.

1.4.22 *Standard flow* is the flow rate expressed in volume flow rate. ISO standard flow rate is cubic meters per hour or minute (m^3/h or m^3/min) at an absolute pressure of 1.013 bar [14.7 pounds per square inch (psi)] and a temperature of 0°C (32°F). Customary units are standard cubic feet per minute (SCFM) or million standard cubic feet per day (MMSCFD) at an absolute pressure of 14.7 pounds per square inch and a temperature of 60°F.

1.4.23 *Total indicated runout* (TIR), also known as total indicator reading, is the runout of a diameter or face determined by measurement with a dial indicator. The indicator reading implies an out-of-squareness equal to the reading or an eccentricity equal to half the reading.

1.4.24 *Trip speed* (revolutions per minute) is the speed at which the independent emergency overspeed device operates to shut down a variable speed prime mover (see Table 1).

Table 1—Driver Trip Speeds

Driver Type	Trip Speed (% of Maximum Continuous Speed)
Steam turbine	
NEMA Class A[a]	115
NEMA Classes B, C, D[a]	110
Gas turbine	105
Variable speed motor	110
Reciprocating engine	110

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

1.4.25 *Unit responsibility* refers to the responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order. It includes responsibility for reviewing such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, and testing of components.

1.4.26 A *wet critical speed* is a rotor resonant frequency calculated considering the additional support and damping produced by the action of the pumped liquid within internal running clearances at the operating conditions and allowing for flexibility and damping within the bearings.

1.5 References

1.5.1 This standard makes reference to American standards; other international or national standards may be used as mutually agreed between purchaser and vendor provided it can be shown that these standards meet or exceed the American standards referenced.

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

AFBMA[1]

Std 7 *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*

Std 9 *Load Ratings and Fatigue Life for Ball Bearings*

Std 19 *Tapered Roller Bearings–Radial Inch Design*

[1] Anti-Friction Bearing Manufacturers Association, 1235 Jefferson Davis Highway, Arlington, Virginia 22202.

Std 19.1 *Tapered Roller Bearings–Radial Metric Design*
Std 20 *Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types, Metric Design: Conforming to Basic Boundary Plans: Boundary Dimensions, Tolerances and Identification Code.*

AGMA[2]
9000-C90(1990) *Flexible Couplings-Potential Unbalance Classification*
9002 *Bores and Keyways for Flexible Couplings (Inch Series)*

AISC[3]
Manual of Steel Construction

ANSI[4]
B1.1 *Unified Inch Screw Threads (UN and UNR Thread Form)*
B1.20.1 *Pipe Threads, General Purpose (Inch)*
B1.20.3 *Dryseal Pipe Threads (Inch)*
B16.1 *Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800*
B16.5 *Pipe Flanges and Flanged Fittings, Steel Nickel Alloy and Other Special Alloys*
B16.11 *Forged Steel Fittings, Socket-Welding and Threaded*
B16.42 *Ductile Iron Pipe Flanges and Flanged Fitting, Class 150 and 300*
B73.1 *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Processes*
B73.2 *Specification for Vertical In-line Centrifugal Pumps for Chemical Services*
S2.19 *Mechanical Vibration–Balance Quality of Rigid Rotors–Part 1, Determination of Permissible Residual Unbalance*

API
Spec 5L *Specification for Line Pipe*
RP 500A *Classification of Locations for Electrical Installations in Petroleum Refineries*
RP 520 *Sizing, Selection and Installation of Pressure Relieving Devices in Refineries*
Std 526 *Flanged Steel Safety Relief Valves*
Std 550 *Manual on Installation of Refinery Instruments and Control Systems* (oop)
Std 610 *Centrifugal Pumps for General Refinery Service*
Std 611 *General-Purpose Steam Turbines for Refinery Services*
Std 615 *Sound Control of Mechanical Equipment for Refinery Services* (oop)
Std 660 *Shell-and-Tube Heat Exchangers for General Refinery Services*
Std 670 *Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems*
Std 677 *General Purpose Gear Units for Refinery Service*
Manual of Petroleum Measurement Standards, Chapter 15, "Guidelines for the Use of the International System of Units (SI) in the Petroleum and Allied Industries"

ASME[5]
B1.20.1 *Pipe Threads, General Purpose (Inch)*
B16.47 *Large Diameter Steel Flanges: NPS 26 through NPS 60*
B31.3 *Chemical Plant and Petroleum Refinery Piping Boiler and Pressure Vessel Code,* Section V, "Non-destructive Examination"; Section VIII, "Rules for Construction of Pressure Vessels"; and Section IX, "Welding and Brazing Qualifications"

ASTM[6]
A 105 *Specification for Carbon Steel Forgings for Piping Components*
A 106 *Specification for Seamless Carbon Steel Pipe for High-Temperature Service*
A 120 *Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses*
A 153 *Specification for Zinc Coating (Hot Dip) on Iron and Steel Hardware*
A 181 *Specification for Carbon Steel Forgings for General Purpose Piping*

[2] American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314-2730.
[3] American Institute of Steel Construction, 1 East Wacker Drive, Suite 3100, Chicago, Illinois 60601-2001.
[4] American National Standards Institute, 11 West 42nd Street, New York, New York 10036.
[5] American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.
[6] American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103

A 193 *Specifications for Alloy-Steel and Stainless Steel Bolting Materials for High- Temperature Service*
A 194 *Specification for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service.*
A 197 *Specification for Cupola Malleable Iron*
A 247 *Method for Evaluating the Microstructure of Graphite in Iron Castings*
A 269 *Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*
A 278 *Specification for Gray Iron Castings for Pressure Containing Parts for Temperatures up to 650°F*
A 338 *Specification for Malleable Iron Flanges, Pipe Fittings, and Valve Parts for Railroad, Marine and Other Heavy Duty Service at Temperatures up to 650°F (345°C)*
A 395 *Specification for Ferrite Ductile Iron Pressure-retaining Castings for Use at Elevated Temperatures*
A 515 *Specification for Carbon Steel Pressure Vessel Plates for Intermediate and Higher-Temperature Service*
A 524 *Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures*
A 536 *Specification for Ductile Iron Castings*
E 94 *Guides for Radiographic Testing*
E 125 *Reference Photographs for Magnetic Particle Indications on Ferrous Castings*
E 142 *Method for Controlling Quality of Radiographic Testing*
E 709 *Practice for Magnetic Particle Examination*

AWS[7]

D1.1 *Structural Welding Code-Steel*

EEMUA[8]

151 *Liquid Ring Vacuum Pumps and Compressors*

HEI[9]

Performance Standard for Liquid Ring Vacuum Pumps

NACE[10]

MR-01-75 *Sulfide Stress Cracking Resistent Metallic Material For Oil Field Equipment*

Corrosion Engineer's Reference Book

NEMA[11]

SM 23 *Steam Turbines for Mechanical Drive Service*

NFPA[12]

70 *National Electrical Code, Articles 500 and 501*
496 *Purged and Pressurized Enclosures for Electrical Equipment*

OSHA[13]

29 *Code of Federal Regulations Part 1910*

PNEUROP 6612[14]

Acceptance Specification and Performance Tests for Liquid Ring Vacuum Pumps

SSPC[15]

SP 6 *Commercial Blast Cleaning*

TEMA[16]

Standard of Tubular Exchangers Manufacturers Association

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

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

1.6 Unit Conversion

The factors in Chapter 15 of the API *Manual of Petroleum Measurement Standards* were used to convert from customary to SI units; the resulting exact SI units were then rounded off.

[7] American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.
[8] The Engineering Equipment and Materials Users Association, 14-15 Belgrave Square, London, U.K. SWIX8PS.
[9] Heat Exchange Institute, 1230 Keith Building, Cleveland, Ohio 44115.
[10] NACE International, P.O Box 218340, Houston, Texas 77218-8340.
[11] National Electrical Manufacturers Association, 2101 L. Street, N.W., Washington, D.C. 20037.
[12] National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269.
[13] Occupational Safety and Health Standards.
[14] European Committee of Manufacturers of Compressors, Vacuum Pumps and Pneumatic Tools, c/o British Compressed Air Society, Leicestor House & Leicestor Street, London, U K. WCZH 7NN.
[15] Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213-2683.
[16] Tubular Exchanger Manufacturers Association, 25 North Broadway, Tarrytown, New York 10591.

SECTION 2—BASIC DESIGN

2.1 General

2.1.1 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least three years of uninterrupted operation. It is recognized that this is a design criterion.

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

- **2.1.3** The purchaser will specify the equipment's normal and rated operating points on the data sheets. The purchaser will also specify any other anticipated operating conditions.

- **2.1.4** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified by the purchaser.

- **2.1.5** Cooling water design conditions will be specified by the purchaser. Note that cooling water design parameters are particularly critical to the performance of liquid ring machines. The lowest available cooling water temperature will result in the best performance, namely, capacity and suction pressure. The conditions in Table 2 are suggested guidelines.

Table 2—Cooling Water Design Parameters

Conditions	Parameters SI Units	Parameters English Units
Velocity over heat exchange surfaces	1.5-2.5 m/s	5-8 ft/s
Maximum allowable working pressure	≥ 5.2 bar[a]	75 psig
Test pressure	≥ 1.5 × MAWP	115 psig
Maximum pressure drop	1 bar	15 psi
Maximum inlet temperature	30°C	90°F
Maximum outlet temperature	50°C	120°F
Maximum temperature rise	20K	30°F
Minimum temperature rise[b]	10K	20°F
Fouling factor on water side	0.35m^{2}K/kW	0.002 hr-ft^2°F/Btu
Shell corrosion allowance	3.0 mm	0.125 in

Note: The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflicting design. The criterion for velocity over heat exchanger surfaces is intended to minimize water-side fouling, the criterion for minimum temperature rise is intended to minimize the use of cooling water. It is accepted that the specified minimum temperature rise may be too restrictive for vacuum pumps handling condensable vapors The purchaser will approve the final selection

[a] Gauge pressure

[b] Lower temperature rise may be necessary depending upon conditions and pending purchaser approval.

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

2.1.6 Equipment shall be designed to run to the trip speed and relief valve settings without damage.

- **2.1.7** The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance. Any special clearance or safe access areas located on the skid will be specified by the purchaser.

- **2.1.8** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser on the data sheets and shall meet the requirements of NFPA 70, Articles 500, 501, 502, and 504 as well as local codes specified and furnished by the purchaser.

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

2.1.10 All equipment shall be designed to permit rapid and economic maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or cylindrically doweled) and manufactured to ensure accurate alignment on reassembly.

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

2.1.12 In designing the liquid ring unit, the vendor shall take into account that many factors (such as piping loads, alignment at operating conditions, supporting structure, and handling during shipment and installation) may adversely affect site performance.

- **2.1.13** The purchaser will specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), as well as the weather and environmental conditions in which the equipment must operate (including maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions). The unit and its auxiliaries shall be suitable for operation under these specified conditions. For purchaser's guidance, the vendor shall list in the proposal any special protection that the purchaser is required to supply.

2.1.14 All equipment shall be additionally suitable for running on air during commissioning. The vendor shall provide air performance curves, operating guidelines, and any additional features required.

Note: It may be necessary to use a different ring liquid to run on air.

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

• **2.1.16** When specified, the equipment feet shall be provided with vertical jackscrews and shall be drilled with pilot holes that are accessible for use in final doweling.

2.1.17 A guide to liquid ring vacuum pump and compressor nomenclature will be found in Appendix B.

2.2 Casings

2.2.1 The stress used in design for any given material shall not exceed the values given for that material in Section VIII, Division 1, of the ASME Code. For cast materials, the factor specified in the code shall be applied. Pressure casings of forged steel, rolled and welded plate, or seamless pipe with welded cover shall comply with the applicable rules of Section VIII, Division 1, of the ASME Code. Manufacturer's data report forms and stamping, as specified in the code, are not required.

2.2.2 The maximum allowable working pressure of the casing shall be at least equal to the specified relief valve setting.

2.2.3 Where more than one compression stage is incorporated within a single casing, the whole of that casing shall be designed for the maximum allowable working pressure of the higher pressure stage.

2.2.4 Casings and supports shall be designed to have sufficient strength and rigidity to limit any change of shaft alignment at the coupling flange, caused by the worst combination of allowable pressure, torque, and piping forces and moments, to 50 micrometers (0.002 inch) at static conditions. Under dynamic conditions, the calculated shaft deflection at the coupling flange shall not exceed 125 microinches (0.005 inch). Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews (see Appendix C).

2.2.5 The use of tapped holes in vacuum and pressure parts shall be minimized. To prevent leakage in vacuum and pressure sections of casings, metal equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and tapped holes. The depth of the tapped holes shall be at least one and one half times the stud diameter.

2.2.6 Bolting shall be furnished as specified in 2.2.6.1 through 2.2.6.4.

2.2.6.1 The details of threading shall conform to ANSI B1.1.

• **2.2.6.2** Studs are preferred to cap screws and shall have the first one and one half threads removed at both ends. When specified, studs shall be supplied.

2.2.6.3 Material grade markings shall be located on the nut end of the exposed stud.

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

2.2.6.5 Slotted nut, or spanner-type bolting shall not be used unless specifically approved by the purchaser.

• **2.2.7** Jackscrews and cylindrical casing alignment dowels or shoulders shall be provided to facilitate disassembly and reassembly. When jackscrews are specified or required as a means of parting contacting faces, one of the faces shall be relieved (counterbored or recessed) to prevent a leaking joint or improper fit caused by marring of the face.

• **2.2.8** When specified, hold-down or foundation bolt holes shall be spot faced to a diameter three times that of the hole.

2.3 Casing Connections

2.3.1 Casings with double flow inlet or discharge connections shall, unless specified otherwise, be furnished with manifolds to a single terminal point connection. The manifolds shall be designed for the same vacuum and maximum allowable working pressure as the casing.

• **2.3.2** Inlet and outlet connections shall be flanged or machined and studded, oriented as specified on the data sheets, and suitable for the maximum allowable working pressure of the casing as defined in 1.4.10.

2.3.3 Casing openings for piping connections shall be at least NPS ½ and for flammable or toxic service shall be flanged or machined and studded, or threaded and seal welded. When threaded connections are approved for nonflammable, nontoxic service, they shall comply with the requirements of 2.3.3.1 through 2.3.3.5.

2.3.3.1 Threaded connections shall be NPS ½ through 1½ nominal pipe sizes only.

• **2.3.3.2** When specified, a pipe nipple, preferably not more than 150 millimeters (6 inches) long, shall be screwed into the threaded opening and shall comply with the requirements of 2.3.3.2.1 through 2.3.3.2.3. Additional fittings may be used if space is restricted.

2.3.3.2.1 The pipe nipple shall meet the minimum schedules listed in Table 3.

2.3.3.2.2 The pipe nipple shall be provided with a flange at its outer end.

2.3.3.2.3 The nipple and flange materials shall meet the requirements of 2.3.5.

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

2.3.3.4 Pipe threads shall be taper threads conforming to ANSI B1.20.1.

2.3.4 For flammable and toxic service the threaded connection shall be seal welded; however, seal welding is not permitted on cast iron equipment, for instrument connections, or where disassembly is required for maintenance. Seal-welded joints shall be in accordance with ASME B 31.3.

2.3.5 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping (see 2.3.3.2.3 and 2.9.3.5).

2.3.6 Openings for NPS 1¼, 2½, 3½, 5, 7, and 9 shall not be used.

2.3.7 Tapped openings not connected to piping shall be plugged with solid plugs furnished in accordance with ASME B16.11. As a minimum, these plugs shall meet the material requirements of the casing. Plugs that may later require removal shall be of corrosion resistant material. A lubricant that meets the proper temperature specification shall be used on all threaded connections. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs are not permitted.

2.3.8 Flanges shall conform to ASME B16.1, B 16.5, or B 16.42 as applicable, except as specified in 2.3.8.1 through 2.3.8.4.

2.3.8.1 Cast iron flanges shall be flat-faced.

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

2.3.8.3 Flanges that are thicker or have a larger outside diameter than that required by ASME B16.5 or B16.47 Series "B" are acceptable.

2.3.8.4 Connections other than those covered by ASME B16.5, B16.47 Series "B" require the purchaser's approval. Unless otherwise specified, mating parts for these nonstandard flanges shall be furnished by the vendor.

2.3.9 Machined and studded connections shall conform to the facing and drilling requirements of ASME B16.1, B16.5, or B16.42. Studs and nuts shall be furnished installed. The first one and one half threads at both ends of each stud shall be removed. Connections larger than those covered by ASME shall meet the requirements of 2.3.8.4.

2.3.10 All of the purchaser's connections shall be accessible for disassembly without the machine being moved.

2.3.11 Casings shall be provided with a vent connection unless they are self-venting by the arrangement of the piping.

2.3.12 Casings shall be provided with sufficient drains to ensure complete drainage.

2.3.13 Welded branches of one inch nominal size or less shall be reinforced by gusset plates or otherwise adequately supported to avoid a fatigue failure at the point of attachment, particularly where a valve or other mass is supported from the branch.

2.4 External Forces and Moments

The manufacturer shall specify the maximum allowable external forces and moments that the compressor or vacuum pump casing will withstand. These shall be at least equal to the values calculated in accordance with NEMA SM-23. The allowable forces and moments shall be shown on the outline drawing.

2.5 Rotating Elements

2.5.1 Rotating assemblies shall be designed to be stiff enough to prevent contact between the rotor and the casing when operating at the maximum allowable differential pressure for all possible operating conditions. Calculated deflection of the shaft at the seals shall not exceed 50 micrometers (0.002 inches).

2.5.2 The impeller shall be either secured to the shaft by an interference fit or keyed, and be capable of transmitting a torque not less than 2.5 times that required for any specified duty, and provided with an arrangement for positive axial location.

2.5.3 Solid rotors are preferred. Hollow rotors will be acceptable only if furnished in compliance with one of the requirements specified in 2.5.3.1 or 2.5.3.2.

2.5.3.1 The rotor is continuously self-venting.

2.5.3.2 The rotor is provided with a plug to allow complete venting of any accumulated gas before beginning any maintenance activity.

2.5.4 Shafts shall be made of one piece, forged steel or hot rolled bar stock and be of ample size to transmit the maximum torque required under any specified operating conditions and to withstand continuously all stresses resulting from supported weights, thrusts, and starting, including direct-on-line motor starting.

2.5.5 Shafts shall be provided with renewable shaft sleeves (that are removable without machining) in the shaft sealing areas. The sleeves shall be of wear-, corrosion-, and erosion-resistant material. Sleeves shall be ground and polished on their outside surface or finished for the specific seal application. Sleeves shall be positively located on the shaft and shall be not less than 2.5 millimeters (0.1 inches) thick.

2.5.6 With the purchaser's approval, sleeves may be omitted provided the proposal so states and the shaft is constructed of an equivalent material and has equal finish to that of a sleeve. Shafts or stub shafts shall include centers to permit refinishing.

2.5.7 For shafts that require sleeve gaskets to pass over threads, the threads shall be at least 2 millimeters (1/16 inches) less than the internal diameter of the gasket, and the diameter transition shall be chamfered 15-20 degrees to avoid damage to the gasket.

2.5.8 Shaft sleeves shall be sealed at one end, and the shaft-sleeve assembly shall extend at least 3 millimeters (1/8 inches) beyond the outer face of the seal end plate. Leakage between the shaft and the sleeve thus cannot be confused with leakage through the mechanical seal faces.

2.5.9 Shafts shall be machined and properly finished throughout their length so that there is no more than 25 micrometers (0.001 inches) total indicated run-out. Shaft sleeves shall have no more than 50 micrometers (0.002 inches) total indicated run-out on the outside diameter.

2.6 Mechanical Shaft Seals

• **2.6.1** Mechanical seals shall be furnished. When specified, cartridge type seals shall be furnished.

2.6.2 The mechanical seal shall minimize leakage from or into the vacuum pump or compressor over the entire range of specified operating conditions, during shut-down, start-up and periods of idleness and shall also be suitable for operation of the machine on air.

2.6.3 Seals shall withstand the maximum vacuum and maximum allowable working pressure. Component parts of the seals shall be suitable for the specified service conditions.

• **2.6.4** Where seal face leakage must be contained, dual seals or single seals plus auxiliary shaft sealing devices may be specified by the purchaser. Venting, flushing, or blanketing the space between the primary mechanical seal and the auxiliary sealing device, or between mechanical seals, shall be accomplished by means of tapped openings of the appropriate size but not less than NPS ½, unless agreed to by the purchaser. The arrangement of seal fluid piping shall be approved by the purchaser.

2.6.5 Seals shall be removable without removing the vacuum pump or compressor end housing, inlet or discharge piping, or disturbing the driver.

2.6.6 Mechanical seal materials shall be proposed by the vendor and approved by the purchaser.

2.6.7 The seal end plate component parts shall be satisfactory for at least the maximum design vacuum or maximum allowable working pressure and operating temperature and shall have sufficient rigidity to avoid any distortion that would impair seal operation, including distortion that may occur during tightening of the bolts to set gasketing. Provisions shall be made for centering the seal end plate stuffing box bore with either an inside diameter or an outside diameter register fit. A minimum of 3-millimeter (0.125-inch) thick shoulder shall be provided to prevent axial movement of the mechanical seal seat as a result of chamber under or over pressure. Seal end plate bolting shall be based on specified operating temperature and maximum allowable working pressure and shall be in accordance with Section VIII, Division I, of the ASME Code, except that no fewer than four bolts shall be used.

2.6.8 Gland plate connections shall be identified by stamping on the seal end plate the seal fluid inlet and outlet and vent and drain connections. When required by seal design, direction of rotation shall be shown on each gland plate.

• **2.6.9** The vendor shall furnish all mechanical seal piping and accessories as specified by the purchaser. See Appendix E for typical seal flush plans. The seal piping system, including pipe, tubing, fittings, valves, strainers, orifices, and separators, etc., shall be as specified in 3.7. The seal manufacturer and the vacuum pump or compressor vendor shall jointly establish the seal chamber circulation rate and shall advise the purchaser of the condition required in the seal chamber to ensure proper seal operation. In vacuum service, the seal design shall be suitable to seal against atmospheric pressure when the pump is not operating.

• **2.6.10** When specified for flammable fluids, a non-sparking throttle bushing shall be provided to minimize leakage in the event of a complete seal failure. The diametral clearance at the bushing bore shall not be more than 650 micrometers (0.025 inches).

• **2.6.11** When specified or required, the seal gland plate mating joint shall incorporate a fully confined gasket.

2.7 Dynamics

2.7.1 CRITICAL SPEEDS

2.7.1.1 Critical speeds correspond to resonant frequencies of the rotating assembly/bearing support system. The basic identification of critical speeds is made from the natural frequencies of the system and the forcing phenomena. If the frequency of any harmonic component of a periodic forcing phenomenon is equal to, or approximates, the frequency of any mode of the rotating assembly vibration, a condition of resonance may exist. If resonance exists at a finite speed, that speed is called a critical speed.

2.7.1.2 A rotor-bearing support system in resonance will have its normal vibration displacement amplified. The magnitude of amplification and the rate of phase angle change are related to the amount of damping in the system and the mode shape taken by the rotor.

Note: Lateral critical speeds are not usually a matter of concern for liquid ring compressors and vacuum pumps, as their first lateral critical speed (dry) is usually above their operating speed

2.7.1.3 An exciting frequency may be less than, equal to, or greater than the rotational speed of the rotating assembly. Potential exciting frequencies that are to be considered in the design of rotor-bearing systems shall include, but are not limited to, the following sources:

a. Unbalance in the rotating assembly system.
b. Internal rubs.
c. Blade or vane, passing frequencies.
d. Gear-tooth meshing and side bands.
e. Coupling misalignment.
f. Loose rotating assembly system components.
g. Ball and race frequencies of antifriction bearings.

2.7.1.4 Resonance of structural support may adversely affect the rotor vibration amplitude. Resonance of support systems within the vendor's scope of supply shall not occur at the operating speed of a fixed speed machine or at any speed within the operating range of a variable speed machine.

2.7.1.5 The vendor who is specified to have unit responsibility shall assure that the drive-train (turbine, gear, motor, and the like) critical speeds (rotating assembly lateral, system torsional, impeller blade modes, and the like) will not excite any critical speed of the machinery being supplied and that the entire train is suitable for the specified operating speed range, including any starting-speed detent (hold-point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for his review and included in the instruction manual for his guidance.

2.7.1.6 Rotating assemblies shall be designed such that their first dry critical speed is at least 120 percent of the maximum continuous or trip speed (whichever is greater).

Note Wet critical speeds are not of a concern since they occur at speeds higher than dry critical speeds.

● **2.7.1.7** When specified, the equipment vendor shall make a lateral critical speed analysis to determine that the critical speeds of the driver and compressor/vacuum pump are compatible and to assure acceptable amplitudes of vibration at any speed from zero to trip. When mutually agreed to between the vendor and purchaser, a typical lateral critical speed analysis may be provided for the selection being offered.

2.7.1.8 Excitations of undamped torsional natural frequencies may come from many sources, which should be considered in the analysis. These sources may include, but are not limited to, the following:

a. Gear effects such as pitch line runout.
b. Start-up conditions such as speed detents (under inertial impedances) and other torsional oscillations.
c. Torsional transients such as start-ups of synchronous electric motors.
d. Torsional excitation from drivers such as electric motors and reciprocating engines.
e. Hydraulic governor and electronic feedback and control loop resonances from variable-frequency motors.
f. Unbalance.

2.7.1.9 The undamped torsional natural frequencies of the complete train shall be at least 10 percent above or 10 percent below any possible excitation frequency at the operating speed of a fixed speed machine or within the operating speed range of a variable speed machine.

2.7.1.10 In addition to multiples of running speeds, torsional excitations that are not a function of operating speeds or that are nonsynchronous in nature shall be considered in the torsional analysis when applicable and shall be shown to have no adverse effect. Identification of these frequencies shall be the mutual responsibility of the purchaser and the vendor.

2.7.1.11 When torsional resonances are calculated to fall within the margin specified in 2.7.1.9, (and the purchaser and vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted) a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

● **2.7.1.12** When specified, the vendor shall perform a torsional vibration analysis of the complete coupled train and shall be responsible for directing the modifications necessary to meet the requirements of 2.7.1.8 through 2.7.1.11.

2.7.2 VIBRATION AND BALANCING

2.7.2.1 Rotating components shall be statically or dynamically balanced in accordance with vendor's standard requirements.

2.7.2.2 The unfiltered vibration for all anti-friction bearing vacuum pumps and compressors, measured in any direction on the bearing housing during the shop test and field operation at rated speed and specified operating pressures, shall not exceed the velocity or displacement values, whichever are more restrictive, shown in Figure 2. Filtered vibration shall be measured at running-speed frequency, vane passing frequency or frequencies, and any other frequencies specified by the purchaser.

● **2.7.2.3** When specified by the purchaser, the vendor shall demonstrate that the vacuum pump or compressor can operate at the quoted maximum and minimum pressure ratios and capacity without exceeding the limits specified in 2.7.2.2.

2.8 Bearings, Bearing Housings, and Lubrication

2.8.1 BEARINGS

2.8.1.1 Both radial and thrust bearings shall be the vendor's standard antifriction design (ball or roller).

2.8.1.2 Antifriction bearings shall be selected to give a minimum L_{10} life of 50,000 hours in continuous operation at normal operating duty but not less than 32,000 hours at maximum axial and radial loads and normal speed. (The L_{10} life is the number of hours at the rated bearing load and speed that 90 percent of a group of identical bearings will complete or exceed before the first evidence of failure.)

2.8.1.3 Bearings shall be sized for continuous operation under the most adverse specified operating conditions. Calculations of the loads shall include, but shall not be limited to, the following factors:

a. Fouling and variation in clearances up to twice the design internal clearances.
b. Step thrust from all diameter changes.
c. Stage differential pressure.
d. Variations in inlet and discharge pressure.
e. External loads from the driving equipment.

2.8.1.4 Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and setting of the bearings' clearance or preload.

2.8.1.5 Antifriction bearings shall be retained on the shaft and fitted into housings in accordance with the requirements of AFBMA Standard 7; however, the device used to lock ball thrust bearings to the shaft shall be restricted by a nut with a tongue-type lock washer, for example, Series W.

2.8.1.6 Unless otherwise specified or required, non-angular contact type antifriction bearings with AFBMA symbol 3 internal clearances (C3) shall be provided.

Single or double row bearings shall be of the Conrad type (no filling slots). Pumps or compressors using other than C3 clearance bearings shall have a stainless steel plate on each bearing housing, clearly showing the bearing identification and the AFBMA internal clearance symbol.

Note: Bearings with AFBMA symbol 0 (normal) internal clearance (C0) may be required to maintain proper rotor axial position relative to the casing to prevent metal to metal contact.

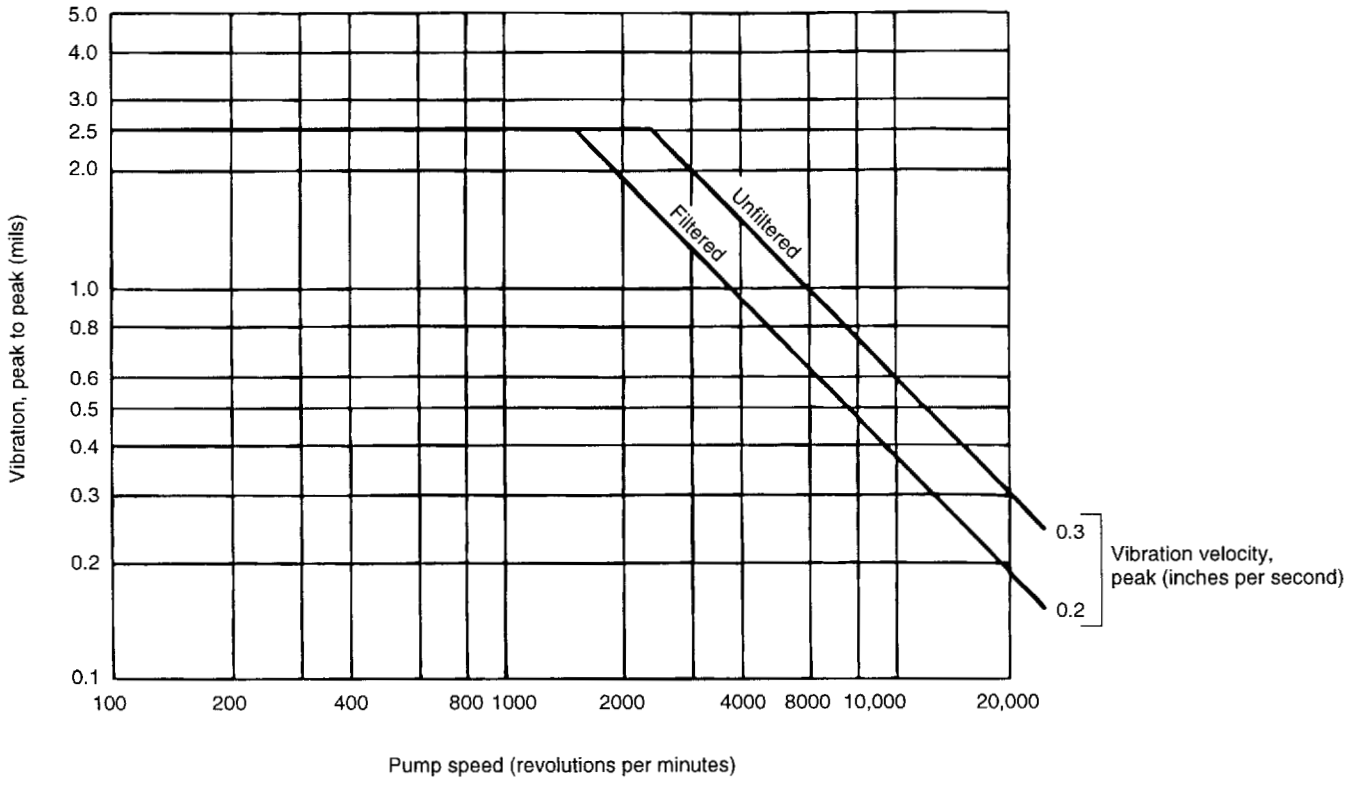


Figure 2—Bearing-Housing Vibration Limits (Antifriction Bearings)

2.8.2 BEARING HOUSINGS

2.8.2.1 Bearing housings shall be equipped with labyrinth-type seals or lip-type seals where the shaft passes through the housing.

2.8.2.2 Bearing housings for grease lubricated bearings shall be provided with stainless steel pressure type grease fittings for filling while operating and a visible discharge port for observing the displaced grease.

2.8.2.3 Where the gas or liquid is flammable or toxic, cantilevered shaft support structures bolted to steel cases shall also be steel.

● **2.8.2.4** When specified, bearing housings for oil-lubricated non-pressure-fed bearings shall be provided with tapped and plugged fill and drain openings at least ½ inch National Pipe Thread (NPT) in size. Tape shall not be applied to threads of plugs inserted into oil passages. The housings shall be equipped with constant-level sight-feed oilers at least 0.1 liters (4 ounces) in size, with a positive level positioner (not a set screw), heat resistant containers (not subject to sunlight–or heat induced opacity or deterioration), and protective wire cages. When specified, the oilers shall meet the purchaser's preference. A permanent indication of the proper oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings or other durable means.

● **2.8.2.5** When specified, bearing housings shall be equipped with replaceable labyrinth-type end seals and deflectors shall be provided. The seals and deflectors shall be made of nonsparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

● **2.8.2.6** When specified, provisions shall be made for mounting one radial vibration transducer in each bearing housing. The transducer location shall be as specified in API Standard 670 (see 3.2.4.6).

● **2.8.2.7** When specified, thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API Standard 670.

2.8.3 LUBRICATION

2.8.3.1 Unless otherwise specified, bearings and bearing housings shall be arranged for grease lubrication.

● **2.8.3.2** When specified, bearings and bearing housings shall be arranged for hydrocarbon oil lubrication.

2.8.3.3 Any points that require grease lubrication shall have suitable extension lines to permit access during operation.

● **2.8.3.4** When specified, provisions shall be made for a circulating or an oil mist system. The system design and arrangement shall be agreed upon by the purchaser and the vendor.

2.9 Materials

2.9.1 GENERAL

2.9.1.1 Materials of construction shall be the manufacturer's standard for the specified operating conditions, except as required or prohibited by the data sheets or this standard (see 3.7 for requirements for piping material). See Appendix F for typical materials. The metallurgy of all major components shall be clearly stated in the vendor's proposal.

2.9.1.2 Pressure retaining parts of machines that are in flammable or toxic services shall be steel.

2.9.1.3 Materials shall be identified in the proposal with their applicable ASTM, AISI, ASME, or SAE[1] numbers, including the material grade (see Appendix F). 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.

2.9.1.4 The vendor shall specify the ASTM optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The purchaser may consider specifying additional tests and inspections, especially for materials used in critical components (see 5.2.3, Item i).

2.9.1.5 Minor parts that are not identified (such as nuts, springs, washers, gaskets, and keys) shall have corrosion resistance at least equal to that of specified parts in the same environment.

● **2.9.1.6** The purchaser will specify any corrosive agents present in the gas and ring liquid and in the environment, including constituents that may cause stress corrosion cracking.

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

Note. Overlays or hard surfaces that contain more than 0.10 percent 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.

2.9.1.8 Where mating parts such as studs and nuts of AISI Standard Type 300 stainless steel or materials with similar

[1] Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.

galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification and be compatible with the gas.

Note. Torque loading values will be considerably different with and without antiseizing compound.

- **2.9.1.9** Materials exposed to a sour environment (wet H_2S) as defined by NACE MR-01-75 shall be in accordance with the requirements of that standard. Ferrous materials not covered by NACE MR-01-75 shall be limited to a yield strength not exceeding 6200 bar (90,000 pounds per square inch) and a hardness not exceeding Rockwell C22.

Components that are fabricated by welding shall be post-weld heat treated, if required, so that both welds and heat-affected zones meet the yield strength and hardness requirements. The purchaser will specify on the data sheets the presence of H_2S in the process gas.

- **2.9.1.10** When dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples that can result in serious corrosion of the less noble material may be created. If such conditions exist, the purchaser and the vendor should select materials in accordance with the NACE *Corrosion Engineer's Reference Book.*

2.9.1.11 Materials, casting factors, and the quality of any welding shall be equal to those required by Section VIII, Division 1, of the ASME Code. The manufacturer's data report forms, as specified in the code, are not required.

2.9.1.12 The use of ASTM A 515 steel is prohibited. Low carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or low temperatures. Therefore, only fully killed, normalized steels made to fine grain practice are acceptable.

- **2.9.1.13** Copper and copper alloys (excluding Monel or its equivalent, bearing babbitt, and precipitation hardened stainless steels) shall not be used for parts of vacuum pumps, compressors or auxiliaries in contact with corrosive gas or with gases capable of forming explosive copper compounds. It will be the responsibility of the purchaser to note such gas characteristics on the inquiry data sheets.

2.9.2 CASTINGS

2.9.2.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shotblasting, chemical cleaning, or any other standard method. Mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

2.9.2.2 The use of chaplets in pressure castings shall be held to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition compatible with the casting.

2.9.2.3 Ferrous castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 2.9.2.3.1 and 2.9.2.3.2.

2.9.2.3.1 Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure based on the requirements of Section VIII, Division 1 and Section IX of the ASME Code.

2.9.2.3.2 Cast gray iron or nodular iron may be repaired by plugging within the limits specified in ASTM A 278, A 395, or A 536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All repairs that are not covered by ASTM specifications shall be subject to the purchaser's approval.

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

- **2.9.2.5** When specified, nodular iron castings shall be produced in accordance with ASTM A 395. The production of the castings shall also conform to the conditions specified in 2.9.2.5.1 through 2.9.2.5.5.

2.9.2.5.1 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. These specimens shall have a minimum impact value of 14.0 joules (10 foot pounds) at room temperature.

2.9.2.5.2 The Keel or Y block cast at the end of the pour shall be at least as thick as the thickest section of the main casting.

2.9.2.5.3 Integrally cast test bosses, preferably at least 25 millimeters (1 inch) in height and diameter, shall be provided for all critical areas of the casting for subsequent removal for the purposes of hardness testing and microscopic examination. Critical areas are typically heavy sections, section changes, high stress points, flanges, and other points agreed upon by the purchaser and the vendor. Classification of graphite nodules shall be in accordance with ASTM A 247.

2.9.2.5.4 An as-cast sample from each ladle shall be chemically analyzed.

2.9.2.5.5 Brinell hardness readings shall be made on the actual casting at feasible locations including section changes and flanges. Sufficient surface material shall be removed before hardness readings are made to eliminate any skin effect. Readings shall also be made at the extremities of the casting at locations that represent the section poured first and last. These shall be made in addition to Brinell readings on the keel or Y blocks.

2.9.3 WELDING

2.9.3.1 Welding of piping and pressure containing parts, as well as any dissimilar metal welds and weld repairs, shall be performed and inspected by personnel and procedures qualified in accordance with Section VIII, Division 1 and Section IX of the ASME Code.

2.9.3.2 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 2.9.1.11). Repair welds shall be nondestructively tested by the same method used to detect the original flaw. As a minimum, the inspection shall be by the magnetic particle method, in accordance with 4.2.2.4 for magnetic material and by the liquid penetrant method in accordance with 4.2.2.5 for nonmagnetic material.

2.9.3.3 Unless otherwise specified, all welding other than that covered by Section VIII, Division 1, of the ASME Code and ASME B31.3, such as welding on base-plates, nonpressure ducting, lagging, and control panels, shall be performed in accordance with AWS D1.1.

• **2.9.3.4** When specified, pressure containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 2.9.3.4.1 through 2.9.3.4.4.

2.9.3.4.1 Plate edges shall be inspected by magnetic particle or liquid penetrant examination as required by Section VIII, Division 1, UG-93 (d)(3), of the ASME Code.

2.9.3.4.2 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.

2.9.3.4.3 Pressure-containing welds, including welds of the case to horizontal- and vertical-joint flanges, shall be full-penetration welds.

2.9.3.4.4 Casings fabricated from materials that, according to Section VIII, Division 1, of the ASME code, require post-weld heat treatment shall be heat treated regardless of thickness.

• **2.9.3.5** When specified, connections welded to pressure casings shall be installed as specified in 2.9.3.5.1 through 2.9.3.5.5.

• **2.9.3.5.1** In addition to the requirements of 2.9.3.1, the purchaser may specify that magnetic particle inspection or liquid penetrant inspection of welds is required.

2.9.3.5.2 Auxiliary piping welded to chromium-molybdenum alloy steel or 12 percent chrome steel components shall be of the same material, except that chromium-molybdenum alloy steel pipe may be substituted for 12 percent chrome steel pipe.

2.9.3.5.3 When heat treatment is required, piping welds shall be made before the component is heat treated.

• **2.9.3.5.4** When specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawings shall show weld designs, size, material, and pre- and post-weld heat treatments.

2.9.3.5.5 All welds shall be heat treated in accordance with Section VIII, Division 1, UW-10 and UW-40, of the ASME Code.

• 2.9.4 LOW TEMPERATURE

For operating temperatures below –30°C (–20°F) or when specified for other low ambient temperatures, steels shall have, at the lowest specified temperature, an impact strength sufficient to qualify under the minimum Charpy V-notch impact energy requirements of Section VIII, Division 1, UG-84, of the ASME code. For materials and thicknesses not covered by the code, the purchaser will specify the requirements on the data sheets.

2.10 Nameplate and Rotation Arrows

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

2.10.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment at a readily visible location. Nameplates and rotation arrows (if attached) shall be of AISI Standard Type 300 stainless steel or nickel-copper alloy (Monel or its equivalent). Attachment pins shall be of the same material. Welding is not permitted.

• **2.10.3** The purchaser's item number, the vendor's name, the machine's serial number, and the machine's size and type, as well as its minimum and maximum allowable design limits and rating data (including pressures, temperatures, speeds, and power), maximum allowable working pressures and temperatures, hydrostatic test pressures, and critical speeds, shall appear on the machine's nameplate or data plate. The purchaser will specify on the data sheets whether customary or SI units are to be shown.

SECTION 3—SYSTEM DESIGN

3.1 Ring Liquid System

3.1.1 GENERAL

● **3.1.1.1** Unless otherwise specified, a system shall be furnished to supply the ring liquid at a suitable pressure and temperature to the vacuum pump or compressor. Typical systems are shown in Appendix D. The purchaser will specify the system required.

Note: A liquid ring pump or compressor requires a ring liquid to operate. Typically, the system required to provide this liquid is furnished by the vendor. The extent of the vendor's scope of supply depends upon how the vacuum pump or compressor is integrated into the user's process.

3.1.1.2 The ring liquid system may include, but need not be limited to the following components, as specified or required (see 3.1.2 through 3.1.8):

a. Separator to disengage the ring liquid from the discharge gas stream. This separator may also serve as a storage vessel.
b. Cooler.
c. Strainer or filter.
d. Ring liquid pump.
e. Interconnecting piping.
f. Check valves.
g. Ring liquid purge system.

3.1.1.3 The ring liquid used shall be mutually agreed upon by the purchaser and the vendor. Purchaser will provide composition and properties of the ring liquid.

3.1.1.4 The system shall be designed to supply the required quantity of ring liquid for all specified operating conditions including start up and "run-in" on air. The system shall be designed and arranged to insure correct ring liquid level during start-up and operation.

● **3.1.1.5** The purchaser will specify whether the ring liquid components are to be mounted on the machine base or on a separate skid.

3.1.1.6 Unless otherwise specified, the ring liquid system, its arrangement (see 2.1.7), and controls shall be subject to purchaser review.

● **3.1.1.7** Coolers, filters, separators, drain traps, and other pressure vessels within the scope of Section VIII, Division 1, of the ASME Code shall conform to the code and, if specified by the purchaser, shall be code stamped.

3.1.2 RING LIQUID SEPARATOR

● **3.1.2.1** If a separator is specified, it shall be designed to separate the discharge gas from the ring liquid. Vendor shall advise the actual gas velocity in the separator vapor space.

● **3.1.2.2** When specified, the vendor shall state the quantity of the ring liquid which will remain entrained in the gas delivered from the separator at each specified operating condition. The purchaser will specify any limitations on liquid carryover from the system.

Note: Transient conditions such as start-up and shutdown may cause unusual carryover conditions.

● **3.1.2.3** When liquid-liquid separation is specified, the system shall be designed to separate condensed process vapors from the ring liquid and allow their removal. The purchaser shall advise the separation time.

Note: Liquid-liquid separation is usually accomplished in a vessel designed for this purpose or in the same vessel used for liquid-gas separation.

3.1.2.4 Unless otherwise specified, an anti-vortex device shall be installed in the draw-off nozzle for the ring liquid that is recycled to the machine.

● **3.1.2.5** The purchaser will provide the vendor with sufficient data to estimate the extent to which the vapor may be expected to condense within the machine. The vendor shall account for this in the design of the machine and separator and, if necessary, provide facilities for the removal of condensate. The purchaser will specify the pressure in the system into which the condensate is to be discharged.

3.1.3 RING LIQUID COOLER

3.1.3.1 Unless otherwise specified, the cooler shall be a water-cooled, shell-and-tube type, with cooling water on the tube side.

3.1.3.2 Unless otherwise specified, coolers shall be constructed and arranged to allow removal of the tube bundles without dismantling piping or machine components.

3.1.3.3 A removable-bundle design is required for coolers with more than 0.45 square meters (5 square feet) of surface, unless otherwise specified. Removable-bundle coolers shall be in accordance with TEMA Class C and shall be constructed with a removable channel cover. Tubes shall not have an outside diameter of less than 15 millimeters (⅝ inch), and the tube wall shall not have a thickness of less than 1.25 millimeters [18 BWG (0.0049 inch)]. U-bend tubes are not permitted. Coolers shall be equipped with vent and drain connections on their shell and tube sides.

3.1.3.4 The vendor shall include in the proposal complete details of any proposed air-cooled heat exchanger.

● **3.1.3.5** When specified, water-cooled shell-and-tube coolers shall be designed and constructed in accordance with TEMA Class C or R, as specified. When TEMA Class R is

specified, the heat exchanger shall be in accordance with API Standard 660.

3.1.4 RING LIQUID FILTER

3.1.4.1 The ring liquid system shall contain as a minimum a Y-type strainer with a 40-mesh (or finer) screen.

● **3.1.4.2** When specified, or when recommended by the vendor, a ring liquid filter shall be supplied, designed to remove solid particles down to the stated size.

● **3.1.4.3** When specified, the filter shall be the replaceable cartridge, duplex type arranged for online, uninterrupted changeover.

3.1.5 RING LIQUID PUMPS

3.1.5.1 If a ring liquid pump is required, it shall be centrifugal and in accordance with ANSI B73.1 or B73.2, unless otherwise specified.

● **3.1.5.2** The purchaser may specify a pump in accordance with API 610.

3.1.6 RING LIQUID PIPING

3.1.6.1 Ring liquid piping shall be in accordance with the requirements of 3.7.

● **3.1.6.2** When specified by the purchaser, the vendor shall make provision for manual or automatic makeup and draining of the ring liquid while the equipment is operating.

3.1.7 CHECK VALVES

● **3.1.7.1** A check valve is required at the inlet to the vacuum pump or compressor. The purchaser will specify if the valve is to be provided by the vendor.

Note: Low-pressure-drop check valves are required for proper operation of the system.

3.1.7.2 Alternate designs, such as a quick acting isolating valve activated on loss of driver power, may be provided as mutually agreed upon by the purchaser and the vendor.

● **3.1.7.3** When specified, the vendor shall provide a discharge check valve and pressure relief valve.

● 3.1.8 RING LIQUID PURGE SYSTEM

A ring liquid purge system shall be provided when specified or when required to reduce dissolved solids, gases, or condensed vapors to an acceptable level.

3.2 Controls and Instrumentation

3.2.1 GENERAL

3.2.1.2 Unless otherwise specified, controls and instrumentation shall be suitable for outdoor installation.

● **3.2.1.3** The vendor shall provide sufficient performance data for the vacuum pump/compressor to enable the purchaser to design a control system for startup and for all specified operating conditions. When specified, the vendor shall review the purchaser's overall control system for compatibility with vendor furnished control equipment.

3.2.2 CONTROL SYSTEMS

● **3.2.2.1** The purchaser will specify the method of control, the source of the control signal, its sensitivity and range, and the equipment to be furnished by the vendor.

● **3.2.2.2** Unless specified otherwise, controlled recycle bypass from discharge to suction is required. When specified, this shall be supplied by the vendor.

Note: Bypass control can be used for suction pressure control, start-up, and pump protection from cavitation. For certain applications, a vacuum relief valve may be acceptable.

3.2.2.3 For a variable-speed drive, the control signal shall act to adjust the set point of the driver's speed-control system. Unless otherwise specified, the control range shall be from 105 percent of the speed required to maintain ring liquid stability (at the specified control parameter conditions) to maximum continuous speed. Vendor shall advise the minimum speed required to maintain ring liquid stability.

Note: A combination of control modes may be required on drives with a limited speed range and on multiservice or multistream applications.

3.2.2.4 For a variable-speed drive, the equipment and control system shall be equipped with an overspeed trip device independent of the speed control system.

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

3.2.2.6 Actuation of the control signal or failure of the signal or actuator shall neither prevent the speed control system from limiting the speed to the maximum continuous speed nor prevent manual regulation with the hand speed changer.

3.2.3 INSTRUMENT AND CONTROL PANELS

● **3.2.3.1** When specified, a panel shall be provided and shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and

fabricated in accordance with the purchaser's specification. The purchaser will specify whether the panel is to be free-standing, located on the base of the unit, or in another location. The instruments on the panel shall be clearly visible to the operator from the driver control point. A lamp test push button shall be provided. The instruments to be mounted on the panel shall be specified on the data sheets.

3.2.3.2 Panels shall be completely assembled, requiring only connection to the purchaser's external piping and wiring circuits. When more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a single terminal box with terminal posts, mounted on the unit (or its base, if any). Wiring shall be installed in metal conduits or enclosures. All leads and posts on terminal strips, switches, and instruments shall be tagged for identification.

3.2.4 INSTRUMENTATION

3.2.4.1 Minimum Instrumentation

Vendor shall submit his recommendations for instrumentation to ensure safe and reliable operation. The following, as a minimum, shall be included. Refer to Appendix D.

a. Gas inlet pressure.
b. Gas inlet temperature.
c. Ring liquid/gas outlet pressure.
d. Ring liquid/gas outlet temperature.
e. Ring liquid supply temperature.
f. Ring liquid level in separator (not required for once-through or partial recirculation systems).
g. Ring liquid supply pressure, or flow.

3.2.4.2 Temperature Gauges

3.2.4.2.1 Dial-type temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 125 millimeters (5 inches) in diameter and bimetallic type or liquid filled. Black printing on a white background is standard for gauges.

3.2.4.2.2 The sensing elements of temperature gauges shall be in the flowing fluid.

Note: This is particularly important for lines that may run partially full

3.2.4.3 Thermowells

Temperature sensing devices that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with NPS ¾ AISI Standard Type 300 stainless steel separable solid-bar thermowells.

3.2.4.4 Thermocouples and Resistance Temperature Detectors

Where practical, the design and location of thermocouples and resistance temperature detectors shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box. Conduit runs from thermocouple heads to a pull box or boxes located on the baseplate shall be provided.

3.2.4.5 Pressure Gauges

Pressure gauges (excluding built-in instrument air gauges) shall be furnished with Type 316 stainless steel Bourdon tubes and stainless steel movements, 110-millimeter (4½-inch) dials and NPS ½-inch male alloy steel connections. Black printing on a white background is standard for gauges. When specified, liquid-filled gauges shall be furnished in locations subject to vibration. Gauge ranges shall preferably be selected so that the normal operating pressure is in the middle *third* of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 percent. Each pressure gauge shall be provided with a device such as a disc insert or blow-out back designed to relieve excess case pressure.

3.2.4.6 Vibration Detectors

3.2.4.6.1 When specified, accelerometers shall be supplied, installed, and calibrated in accordance with API Standard 670.

3.2.4.6.2 When specified, monitors shall be supplied, installed, and calibrated in accordance with API Standard 670.

3.2.4.7 Solenoid Valves

3.2.4.7.1 Direct solenoid-operated valves shall be used only in clean, dry instrument-air service, shall have Class F insulation or better, and shall have a continuous service rating. When required for other services, the solenoid shall act as a pilot valve.

3.2.4.7.2 Solenoid valves shall not be used in continuous services that may affect normal operations. They may be used in intermittent instrument services.

3.2.4.8 Pressure Relief Valves

3.2.4.8.1 The vendor shall furnish the relief valves that are to be installed on equipment or in piping that the vendor is supplying Other relief valves will be furnished by the purchaser. Relief valves for all operating equipment shall meet

the limiting relief valve requirements defined in API Recommended Practice 520, Parts I and II, and in API Standard 526. The vendor shall determine the size and set pressure of all relief valves related to the equipment for the purchaser's approval. The vendor's quotation shall list all relief valves and shall clearly indicate those to be furnished by the vendor. Relief valve settings, including accumulation, shall take into consideration all possible types of equipment failure and the protection of piping systems (see 5.2.3, Item j).

3.2.4.8.2 Unless otherwise specified, relief valves shall have steel bodies.

• **3.2.4.8.3** When specified, thermal relief valves shall be provided for components that may be blocked in by isolation valves.

3.2.5 ALARMS AND SHUTDOWNS

• 3.2.5.1 General

Switches, control devices, and annunciator display units shall be furnished and mounted by the vendor as specified and may include those listed below. The alarm setting shall precede the shutdown setting.

a. High gas outlet temperature.
b. High gas outlet pressure.
c. High ring liquid outlet temperature.
d. Low ring liquid flow.
e. Low ring liquid level in separator.
f. High ring liquid level separator.
g. High bearing housing vibration.
h. Low mechanical seal fluid pressure.

• 3.2.5.2 Annunciator

The vendor shall furnish a first-out annunciator when an annunciator system is specified. The annunciator shall contain approximately 25 percent spare points and, when specified, shall be arranged for purging. Connections shall be provided for actuation of a remote signal when any function alarms or trips. The sequence of operation shall be as specified in 3.2.5.2.1 through 3.2.5.2.3.

3.2.5.2.1 Alarm indication shall consist of the flashing of a light and the sounding of an audible device.

3.2.5.2.2 The alarm condition shall be acknowledged by operating an alarm-silencing button common to all alarm functions.

3.2.5.2.3 When the alarm is acknowledged, the audible device shall be silenced, but the light shall remain steadily lit as long as the alarm condition exists. The annunciator shall be capable of indicating a new alarm (with a flashing light and sounding horn) if another function reaches an alarm condition, even if the previous alarm condition has been acknowledged but still exists.

3.2.5.3 Alarm and Trip Switches

3.2.5.3.1 Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance. Hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 amperes at 120 volts AC and ½ ampere at 120 volts DC shall be used. Mercury switches shall not be used.

3.2.5.3.2 Unless otherwise specified, electric switches that open (de-energize) to alarm and close (energize) to trip shall be furnished by the vendor.

3.2.5.3.3 Alarm and trip switch settings shall not be adjustable from outside the housing. Alarm and trip switches shall be arranged to permit testing of the control circuit, including, when possible, the actuating element, without interfering with normal operation of the equipment. The vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in a test bypass mode. Unless otherwise specified, shutdown systems shall be provided with switches or another suitable means to permit testing without shutting down the unit.

3.2.5.3.4 The vendor shall furnish with the proposal a complete description of the alarm and shutdown facilities to be provided (see 5.2.3, Item j).

3.2.5.3.5 Pressure-sensing elements shall be of AISI Standard Type 300 stainless steel. Low pressure alarms, which are activated by falling pressure, shall be equipped with a valved bleed or vent connection to allow controlled depressurizing so that the operator can note the alarm set pressure on the associated pressure gauge. High pressure alarms, which are activated by rising pressure, shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure.

• 3.2.5.4 Replacement of Instruments and Controls

When specified, all instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit their replacement while the system is in operation. When shutoff valves are specified for shutdown sensing devices, the vendor shall provide a means of locking the valves in the open position.

3.2.5.5 Housings for Arcing-Type Switches

Particular attention is called to the requirements of 2.1.8 concerning the characteristics of housings for arcing-type switches outlined in the applicable codes.

3.2.6 ELECTRICAL SYSTEMS

- **3.2.6.1** The characteristics of electrical power supplies for motors, heaters, and instrumentation shall be specified. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. The pilot lights shall be installed on the control panels.

- **3.2.6.2** Electrical equipment located on the unit or on any separate panel shall be suitable for the hazard classification specified. Electrical starting and supervisory controls may be either AC or DC.

3.2.6.3 Power and control wiring within the confines of the baseplate shall be resistant to oil, heat, moisture, and abrasion. Stranded conductors shall be used within the confines of the baseplate and in other areas subject to vibration. Measurement and remote-control panel wiring may be solid conductor. Thermoplastic insulation shall be used and shall be covered by a Neoprene or equal sheath for abrasion protection. Wiring shall be suitable for the environmental temperatures specified.

3.2.6.4 Unless otherwise specified, all leads on terminal strips, switches and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 percent spare terminal points.

3.2.6.5 To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on equipment. The clearances required for 600-volt service shall also be provided for lower voltages. To guard against accidental contact, enclosures shall be provided for all energized parts.

- **3.2.6.6** Electrical materials, including insulation, shall be corrosion resistant and non-hygroscopic insofar as is possible. When specified for tropical location, materials shall be given the treatments specified in 3.5.6.6.1 and 3.5.6.6.2.

3.2.6.6.1 Parts (such as coils and windings) shall be protected from fungus attack.

3.2.6.6.2 Unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

3.2.6.7 Control, instrumentation, and power wiring (including temperature element leads) within the confines of the baseplate shall be installed in rigid metallic conduits and boxes, properly bracketed to minimize vibration, and isolated or shielded to prevent interference between voltage levels. Conduits may terminate (and in the case of temperature element heads, shall terminate) with a flexible metallic conduit long enough to permit access to the unit for maintenance without removal of the conduit. If temperature element heads will be exposed to temperatures above 60°C (140°F), a 19-millimeter (¾-inch) bronze hose with four-wall interlocking construction and joints with packed-on (heatproof) couplings shall be used.

3.2.6.8 For Division 2 locations, flexible metallic conduits shall have a liquid tight thermosetting or thermoplastic outer jacket and approved fittings. For Division 1 locations, an NFPA-approved connector shall be provided.

3.2.6.9 AC and DC circuits shall be clearly labeled, connected to separate terminal blocks, and isolated from each other.

3.3 Drivers and Transmissions

- **3.3.1** The type of driver shall be specified. The driver shall be sized to meet the maximum specified operating conditions, including external transmission losses, and shall be in accordance with applicable specifications, as stated in the inquiry and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified by the purchaser.

- **3.3.2** Anticipated process variations that may affect the sizing of the driver (such as changes in the pressure, temperature, or properties of the fluid handled, as well as special plant start-up conditions) shall be specified.

- **3.3.3** The starting conditions for the driven equipment shall be specified, and the starting method shall be mutually agreed upon by the purchaser and the vendor. The driver's starting-torque capabilities shall exceed the speed-torque requirements of the driven equipment. Particular attention shall be given to starting conditions when the machine is used as a vacuum pump and may be required to start with the suction at atmospheric pressure.

3.3.4 For motor driven units, the motor nameplate rating (exclusive of the service factor) shall be at least 110 percent of the maximum power required (including gear and coupling losses) for any of the specified operating conditions. Consideration shall be given to starting conditions. Equipment driven by induction motors shall be rated at the actual motor speed for the rated load condition.

- **3.3.5** In the case of electric motor drives, the purchaser will specify the type of motor and its characteristics and accessories, including the following:

a. Electrical characteristics.
b. Starting conditions (including the expected voltage drop on starting).
c. Type of enclosure.
d. Maximum allowable sound pressure level.
e. Area classification.
f. Type of insulation.

g. Required service factor.
h. Ambient temperature and elevation above sea level.
i. Transmission losses.
j. Temperature detectors, vibration sensors, and heaters, if these are required.
k. Auxiliaries (such as a ventilation blower and instrumentation).

• **3.3.6** The motor's starting-torque requirements shall be met at a specified reduced voltage, and the motor shall accelerate to full speed within a period of time agreed upon by the purchaser and the vendor.

Note: For most applications, the starting voltage is typically 80 percent of the normal voltage, and the time required to accelerate to full speed is generally less than 15 seconds.

3.3.7 Steam turbine drivers shall conform to API 611. Steam turbine drivers shall be sized to deliver continuously 110 percent of the maximum power required for the purchaser's specified conditions while operating at a corresponding speed of the specified steam conditions. Consideration shall be given to starting conditions.

3.3.8 Gears shall conform to API Standard 677.

3.3.9 For drivers that weigh more than 450 kilograms (1000 pounds), the driver feet shall be provided with vertical jackscrews.

3.4 Couplings and Guards

3.4.1 Unless otherwise specified, flexible couplings and guards between drivers and driven equipment shall be supplied by the manufacturer of the driven equipment.

• **3.4.2** Coupling hubs shall be steel. Flexible-disc types shall have discs of corrosion-resistant material. The make, model, materials, service factor, and mounting arrangement of couplings will be specified by the purchaser. A spacer coupling shall be used unless otherwise specified. The spacer shall have a nominal length of at least 125 millimeters (5 inches) and shall permit removal of the coupling, bearings, and seals without disturbing the driver or the suction and discharge piping.

Note: When flexible-element couplings are specified, consideration should be given to designs that will retain the spacer if a flexible element ruptures.

3.4.3 Information on shafts, keyway dimensions (if any), and shaft end movements due to end play and thermal effects shall be furnished to the vendor supplying the coupling.

3.4.4 Couplings and coupling-to-shaft junctures shall be rated for at least the maximum driver power, including any motor service factor.

3.4.5 Couplings shall be keyed. Keys, keyways, and fits shall conform to AGMA 9002. Coupling hubs shall be furnished with tapped puller holes at least ⅜ inch (10 millimeters) in size to aid removal.

• **3.4.6** When specified, the coupling surfaces normally used for checking alignment shall be concentric with the axis of coupling hub rotation within the following limits: 0.5 micrometers total indicated runout per millimeter of shaft diameter (0.0005 inch per inch), with a maximum of 100 micrometers (0.003 inches) total indicated runout. All other diameters not used for location, registration, or alignment shall be to the coupling manufacturer's standard, provided balance requirements are met.

• **3.4.7** When specified, couplings shall be manufactured to meet the balance requirements of AGMA 9000, Class 8. When specified by the purchaser or recommended by the vendor, couplings shall be dynamically balanced in accordance with AGMA 9000. For dynamic balancing, the AGMA balance class shall be mutually agreed upon by the purchaser and the vendor.

• **3.4.8** When specified, limited-end-float couplings with maximum coupling end floats as specified in Table 3 shall be supplied with horizontal-sleeve-bearing motors to prevent the motor rotor from rubbing stationary motor parts.

Note: Couplings with axial elastic centering forces are usually satisfactory without these precautions.

3.4.9 When the vendor is not required to mount the driver, he shall deliver the fully machined half-coupling to the driver manufacturer's plant or any other designated location, together with the necessary instructions for mounting the half-coupling on the driver shaft.

3.4.10 Removable coupling guards shall be furnished and shall be in accordance with the Occupational Safety and Health Administration's requirements for coupling guards.

3.5 Belt Drives

3.5.1 Belt drives shall only be used for equipment of 150 kilowatts (200 brake horsepower) or less and, unless otherwise specified, shall employ multiple-V belts or positive drive belts. Multiple V-belts shall be furnished in either matched sets or banded multi-V designs. All belts shall be oil resistant (that is, they shall have a core of Neoprene or an equivalent material) and shall be of the static-conducting type. The service factor shall not be less than 1.75 times the driver nameplate power rating.

Table 3—Maximum Coupling End Floats

Minimum Motor Rotor End Float		Maximum Coupling End Float	
Millimeters	Inches	Millimeters	Inches
6	0.250	2	0.090
13	0.500	5	0.190

3.5.2 The vendor shall provide a positive belt-tensioning device on all belt drives. This device shall incorporate a lateral adjustable base with guides and hold-down bolts, two belt-tensioning screws, and locking bolts.

3.5.3 The vendor who has unit responsibility shall inform the manufacturer of the connected equipment when a belt drive is to be used. The driver manufacturer shall be provided with the belt drive's radial-load. These characteristics shall be taken into account when the driver is selected.

3.5.4 Belt drives shall meet the requirements of 3.5.4.1 through 3.5.4.7.

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

3.5.4.2 The belt wrap (contact) angle on the small sheave shall not be less than 140 degrees.

3.5.4.3 The shaft length on which the sheave hub is fitted shall be greater than or equal to the width of the sheave hub.

3.5.4.4 The length of a shaft key fitting used to mount a sheave shall not be less than the length of the sheave bore.

3.5.4.5 The sheave shall be mounted on a tapered adapter bushing.

3.5.4.6 To reduce bearing moment loading (belt tension), the sheave overhang distance shall be minimized.

● **3.5.4.7** When specified, sheaves shall meet the balance requirements of ANSI S2.19, Grade 6.3.

3.5.5 Removable guards shall be furnished and shall be in accordance with the Occupational Safety and Health Administrations requirements for guards.

3.6 Mounting Plates

3.6.1 GENERAL

● **3.6.1.1** The equipment shall be furnished with soleplate or a baseplate as specified on the data sheets. The vendor shall mount and align the driver and transmission on the mounting plate prior to shipment. The purchaser will specify either continuously grouted or column mounting (see 3.6.1.2.4 and 3.6.2.4).

3.6.1.2 In 3.6.1.2.1 through 3.6.1.2.11, the term *mounting plate* refers to both baseplate and soleplates.

3.6.1.2.1 The upper surfaces of mounting plates used for mounting the equipment shall be machined parallel. The maximum surface finish shall be 3 micrometers (125 microinches) Ra.

3.6.1.2.2 Mounting plates shall be equipped with vertical jackscrews.

3.6.1.2.3 Unless otherwise specified, alignment positioning screws shall be provided for each driver and gearbox that weighs 225 kg (500 lb) or more to facilitate longitudinal and transverse horizontal adjustment. The lugs holding these jackscrews shall be attached to the mounting plates so that they do not interfere with the installation or removal of the drive element or shims.

3.6.1.2.4 Machinery supports shall be designed to limit a change of alignment to 50 micrometers (0.002 inches) at the coupling flange, in addition to that allowed in 2.2.4 (see 2.4 for allowable piping forces).

● **3.6.1.2.5** When epoxy grout is specified, the vendor shall commercially sandblast, in accordance with SSPC SP 6, all the grouting surfaces of the mounting plates and shall precoat these surfaces with a catalyzed epoxy primer. The epoxy primer shall be compatible with epoxy grout. The vendor shall submit to the purchaser instructions for field preparation of the epoxy primer.

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

3.6.1.2.6 Anchor bolts shall not be used to fasten machinery to the mounting plates.

3.6.1.2.7 Mounting plates shall not be drilled for equipment to be mounted by others. The outside corners of the mounting plates in contact with the grout shall have at least 50 millimeters (2 inch) radii in the plan view.

3.6.1.2.8 Machined mounting surfaces shall extend at least 25 millimeters (1 inch) beyond the outer three sides of equipment feet to facilitate alignment at installation.

3.6.1.2.9 All pads for drivers and gearboxes shall be machined to allow for the installation of shims at least 3 millimeters (⅛ inch) thick under each component. When the vendor mounts the components, a set of stainless steel shims at least 3 millimeters (⅛ inch) thick shall be furnished. All shim packs shall straddle the hold down bolts and any vertical jackscrews.

3.6.1.2.10 Anchor bolts will be furnished by the purchaser.

3.6.2 BASEPLATE

● **3.6.2.1** When a baseplate or skid is specified, the data sheets will indicate the major equipment items to be mounted on it. A baseplate shall be a single unit of fabricated steel construction.

3.6.2.2 Unless otherwise specified, the baseplate shall extend under the pump, driver, and gear.

● **3.6.2.3** When specified, baseplates or skids shall be provided with levelling pads or targets protected by remov-

able covers. The pads or targets shall be accessible for field levelling after installation, with the equipment mounted and the baseplate on the foundations.

• **3.6.2.4** When column mounting is specified, the baseplate shall be of sufficient rigidity to be supported at the specified points without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

3.6.2.5 Unless otherwise specified, fabricated baseplates shall be designed in accordance with AISC *Manual of Steel Construction,* Part 5, Specifications and Codes.

• **3.6.2.6** Single-piece drain-rim or drain-pan baseplates shall be furnished. The rim or pan of the baseplate shall be sloped at least 1:120 toward the pump end, where a tapped drain opening at least 1 inch NPT in size shall be located to affect complete drainage. As a minimum, the drain-rim or drain-pan shall extend underneath the pump or compressor to collect leakage. When specified, more extensive leakage collection shall be provided.

3.6.2.7 The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or machinery mounted on it.

3.6.2.8 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, it shall be provided with at least one grout hole having a clear area of at least 100 square centimeters (19 square inches) and no dimension less than 75 millimeters (3 inches) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members. Where practical, holes shall be accessible for grouting with equipment installed. The holes shall have 13-millimeter (½-inch) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided. Vent holes at least 13 millimeters (½ inch) in size shall be provided at the highest point in each bulkhead section of the baseplate.

• **3.6.2.9** When specified, mounting pads on the bottom of the baseplate shall be provided and shall be in one plane to permit use of a single-level foundation.

• **3.6.2.10** When specified, nonskid metal decking covering all walk and work areas shall be provided on baseplate top.

• **3.6.2.11** When specified, the baseplate mounting pads shall be machined after the baseplate is fabricated.

3.7 Piping

3.7.1 GENERAL

3.7.1.1 Piping design and joint fabrication, examination, and inspection shall be in accordance with ANSI B31.3.

3.7.1.2 Piping systems are defined as follows:

a. Group I:
   1. Vapor piping.
   2. Ring liquid.
   3. Mechanical seal flushing fluid.
   4. Drains and vents.

b. Group II:
   1. Cooling water.
   2. Cooling water drains and vents.
   3. Instrument air.

Systems shall comply with the requirements of Table 4.

Note: Casing connections are discussed in 2.3

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

3.7.1.4 The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, or any auxiliary base area. The piping shall terminate with flanged connections at the edge of the base. The purchaser will furnish only interconnecting piping between equipment groupings and off-base facilities (see 3.7.2.2).

3.7.1.5 The design of piping systems shall achieve the following:

a. Proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.

b. Proper flexibility and normal accessibility for operation, maintenance, and thorough cleaning.

c. Installation in a neat and orderly arrangement adapted to the contour of the machine without obstruction of access openings.

d. Elimination of air pockets by the use of valved vents or nonaccumulating piping arrangements.

e. Complete drainage through low points without disassembly of piping.

3.7.1.6 The use of flanges and fittings shall be minimized. Piping shall preferably be fabricated by bending and welding to minimize the use of flanges and fittings. Welded flanges are permitted only at equipment connections, at the edge of any base, and for ease of maintenance. The use of flanges at other points is permitted only with the purchaser's specific

approval. Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas. Pipe bushings shall not be used. Threaded connections shall be held to a minimum.

3.7.1.7 Pipe threads shall be taper threads in accordance with ASME B 1.20.1. Flanges shall be in accordance with ANSI B 16.5. Slip-on flanges are permitted only with the purchaser's specific approval. Unless otherwise specified, for socket-welded construction, a 1.6-millimeter (1/16-inch) gap shall be left between the pipe end and the bottom of the socket.

3.7.1.8 Connections, piping, valves, and fittings that are 30 millimeters (1¼ inches), 65 millimeters (2½ inches), 90 millimeters (3½ inches), 125 millimeters (5 inches), 175 millimeters (7 inches), or 225 millimeters (9 inches) in size shall not be used.

3.7.1.9 Where space does not permit the use of NPS ½, ¾, or 1 pipe, seamless tubing may be furnished in accordance with Table 3. The make and model of fittings shall be subject to purchaser's approval.

3.7.1.10 The minimum size of any connection shall be NPS ½ nominal pipe size.

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

3.7.1.12 Welding shall be performed by operators and procedures qualified in accordance with Section IX of the ASME code.

3.7.1.13 Pipe plugs shall be in accordance with 2.3.7.

• **3.7.1.14** The extent of and requirements for process piping to be supplied by the vendor shall be specified.

• **3.7.1.15** When specified, the vendor shall review all piping, appurtenances, and vessels immediately upstream and downstream of the equipment and supports. The purchaser and the vendor shall mutually agree on the scope of this review.

3.7.2 INSTRUMENT PIPING

3.7.2.1 The vendor shall supply all necessary piping, valves, and fittings for instruments and instrument panels (see 3.2.3.2).

3.7.2.2 Connections on equipment and piping for pressure instruments and test points shall conform to 3.7.1.4. Beyond the initial ¾-inch isolating valve, NPS ½ piping, valves, and fittings may be used. Where convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Separate secondary ½-inch isolating valves are required for each instrument on a common connection. Where a pressure gauge is to be used for testing pressure alarm or shutdown switches, common connections are required for pressure gauge and switches.

3.8 Special Tools

3.8.1 When special tools and fixtures are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multi-unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the purchaser and the vendor. These or similar tools shall be used during shop assembly and post-test disassembly of the equipment.

3.8.2 When special tools are provided, they shall be packaged in a separate, rugged metal box or boxes and shall be marked "special tools for (Tag/Item Number)." Each tool shall be stamped or tagged to indicate its intended use.

SECTION 4—INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

4.1 General

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

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

4.1.3 The vendor shall provide sufficient advance notice (see 4.3.1.3) to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed.

• **4.1.4** The purchaser will specify the extent of participation in the inspection and testing and the amount of advance notification required.

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

4.1.4.2 Witnessed means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or his representative in attendance. For mechanical running or performance test, this requires written notification of a successful preliminary test.

4.1.4.3 Observed means that the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test.)

4.1.5 Equipment for the specified inspection and tests shall be provided by the vendor.

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

4.2 Inspection

4.2.1 GENERAL

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

a. Necessary certification of materials, such as mill test reports.
b. Test data to verify that the requirements of the specification have been met.
c. Results of documented tests and inspections, including fully identified records of all heat treatment and radiography.
• d. When specified, final assembly maintenance and running clearances.

4.2.1.2 Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.

• **4.2.1.3** In addition to the requirements of 2.9.3.1, the purchaser may specify the following:

a. Parts that shall be subjected to surface and subsurface examination.
b. The type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic examination.

4.2.2 MATERIAL INSPECTION

• 4.2.2.1 General

4.2.2.1.1 When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 4.2.2.2 to 4.2.2.5 shall apply unless other criteria are specified by the purchaser. Cast iron may be inspected in accordance with 4.2.2.4 and 4.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 4.2.2.2 to 4.2.2.5.

4.2.2.1.2 It shall be the vendor's responsibility to review the design limits of all components in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in 4.2.2 shall be removed to meet the quality standards cited, as determined by the Inspection Method specified.

4.2.2.2 Radiography

4.2.2.2.1 Radiography shall be in accordance with ASTM E 94 and ASTM E 142.

4.2.2.2.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-52, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

4.2.2.3 Ultrasonic Inspection

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

4.2.2.3.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 12, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

4.2.2.4 Magnetic Particle Inspection

4.2.2.4.1 Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E 709.

4.2.2.4.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 6 and Section V, Article 25, of the ASME Code. The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E 125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 4.

4.2.2.5 Liquid Penetrant Inspection

4.2.2.5.1 Liquid penetrant inspection shall be in accordance with Section V, Article 6, of the ASME Code.

4.2.2.5.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 8 and Section V, Article 24, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

4.2.3 MECHANICAL INSPECTION

4.2.3.1 During assembly of the system and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically or by another appropriate method to remove foreign materials, corrosion products, and mill scale.

- **4.2.3.2** When specified, the purchaser may inspect for cleanliness the equipment and all piping and appurtenances furnished by or through the vendor before heads are welded to vessels, openings in vessel or exchangers are closed, or piping is finally assembled.

- **4.2.3.3** When specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds, or heat-affected zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

4.3 Testing

4.3.1 GENERAL

4.3.1.1 Equipment shall be tested in accordance with 4.3.2 and 4.3.3. Other tests that may be specified by the purchaser are described in 4.3.4 and 4.3.5.

4.3.1.2 At least six weeks before the first scheduled running test, the vendor shall submit to the purchaser, for his review and comment, detailed procedures for the mechanical running test and all specified running optional tests, including acceptance criteria for all monitored parameters.

4.3.1.3 The vendor shall notify the purchaser not less than five working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than five working days before the new test date.

4.3.2 HYDROSTATIC TEST

4.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1.5 times the maximum allowable working pressure but not less than 1.5 bar gauge (20 pounds per square inch gauge). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

4.3.2.2 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping or in Section VIII, Division 1, of the ASME Code for vessels. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

Table 4—Maximum Severity of Defects in Castings

Type	Defect	Maximum Severity Level
I	Liner discontinuities	1
II	Shrinkage	2
III	Inclusions	2
IV	Chills and chaplets	1
V	Porosity	1
VI	Welds	1

4.3.2.3 Where applicable, tests shall be in accordance with the ASME Code. In the event that a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

4.3.2.4 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed, and tested parts shall be dried at the conclusion of the test.

4.3.2.5 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum of 30 minutes. Large, heavy castings may require a longer testing period–to be agreed upon by the purchaser and the vendor. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

4.3.3 MECHANICAL RUNNING TEST

4.3.3.1 The requirements of 4.3.3.1.1 through 4.3.3.1.3 shall be met before the mechanical running test is performed.

4.3.3.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

4.3.3.1.2 All joints and connections shall be checked for tightness, and any leaks shall be corrected.

4.3.3.1.3 All warning, protective, and control devices used during the test shall be checked, and adjustments shall be made as required.

4.3.3.2 The vendor's standard mechanical running test of the machine shall be conducted at normal speed for a minimum of one hour, and correct operation of the control system, if furnished, shall be demonstrated.

4.3.3.3 The requirements of 4.3.3.3.1 to 4.3.3.3.3 shall be met during the mechanical running test.

4.3.3.3.1 During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 2.7.2.2 and shall be recorded throughout the operating speed range.

- **4.3.3.3.2** When specified while the equipment is operating at maximum continuous speed, and at all other speeds that may have been specified in the test agenda, sweeps shall be made for vibration amplitudes at frequencies other than synchronous speed. As a minimum, these sweeps shall cover a frequency range from 0.25 to 20 times the maximum continuous speed but not more than 3000 hertz (180,000 cycles per minute). If the amplitude of any discrete, nonsynchronous vibration exceeds 20 percent of the allowable vibration as defined in 2.7.2.2 the purchaser and the vendor shall mutually agree on requirements for any additional testing and on the equipment's suitability for shipment.

- **4.3.3.3.3** When specified, recordings shall be made of all real-time vibration data. When specified, a copy of the recordings shall be given to the purchaser.

4.3.3.3.4 If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable, and the shop tests shall be run after these replacements or corrections are made.

- **4.3.3.4** When specified, any of the requirements of 4.3.3.4.1 through 4.3.3.4.7 shall be met during the mechanical running test.

4.3.3.4.1 All purchased vibration probes, transducers, and accelerometers shall be in use during the test. If vibration probes are not furnished by the equipment vendor or if the purchased probes are not compatible with shop readout facilities, then shop probes and readouts that meet the accuracy requirements of API Standard 670 shall be used.

4.3.3.4.2 Shop test facilities shall include instrumentation with the capability of continuously monitoring and plotting rotational speed, vibration amplitude, and phase angle revolutions per minute, peak-to-peak displacement and phase angle (x-y-y´). Presentation of vibration displacement and phase marker shall be by oscilloscope.

4.3.3.4.3 The vibration characteristics determined by the use of the instrumentation specified in 4.3.3.4.1 and 4.3.3.4.2 shall serve as the basis for acceptance or rejection of the machine.

- **4.3.3.4.4** When seismic test values are specified, vibration data (minimum and maximum values) shall be recorded and located (clock angle) in a radial plane transverse to each bearing centerline (if possible), using shop instrumentation during the test.

4.3.3.4.5 Testing with the contract coupling is preferred.

4.3.3.4.6 The mechanical running test shall verify that the operating speed range is free of critical speeds.

4.3.3.4.7 The mechanical running test of a fixed speed machine shall be conducted at normal speed for a minimum of four hours, and correct operation of the control system shall be demonstrated when applicable. In the case of variable speed units, the test program shall be agreed upon by the purchaser and the vendor, and it shall include a period of operation at maximum continuous speed

4.3.4 GAS LEAK TEST

4.3.4.1 Each completely assembled vacuum pump or compressor casing intended for toxic, hazardous, flammable, or hydrogen-rich service shall be tested as specified in 4.3.4.2.

4.3.4.2 Unless otherwise specified, the casing (with the end seals installed) shall be pressurized to the rated discharge pressure, or in the case of vacuum pumps to 1 bar g (15 psig), held at this pressure for a minimum of 30 minutes, and subjected to a soap-bubble test or another approved test to check for gas leaks.

4.3.5 PERFORMANCE TEST

4.3.5.1 Liquid ring vacuum pumps shall be tested in accordance with HEI *Performance Standards for Liquid Ring Vacuum Pumps,* or PNEUROP 6612 standards, or as mutually agreed to between purchaser and vendor.

- **4.3.5.2** When specified, the compressor, together with it's ring liquid system, shall be subjected to a performance test, the extent of which, and the applicable test methods, shall be agreed to between purchaser and vendor.

4.3.5.3 Unless otherwise specified the machine shall be tested on dry air and water.

4.3.5.4 The performance test may be combined with the mechanical running test.

4.3.5.5 For vacuum pumps, test data shall be recorded at one speed at five suction pressures varying from atmospheric pressures to maximum vacuum. For compressors, test data shall be recorded at one speed from minimum discharge pressure to maximum discharge pressure. The points are subject to negotiation between purchaser and vendor.

4.3.5.6 The dry air and water performance shall be within the tolerances given in Table 5.

4.3.5.7 Performance at the rated operating point shall be calculated from test data in accordance with the vendor's standard procedures, or as otherwise specified. Where the test is to be performed under different conditions or with different fluids from those specified, the method of converting the test results to the specified conditions shall also be agreed upon (see Appendix H).

4.3.5.8 If it is necessary to dismantle a pump or compressor for a correction, such as improvement of efficiency, the initial test will not be acceptable, and the final hydrotest, gas

leak test, and performance test shall be repeated after the correction is made.

4.3.5.9 The performance test shall be conducted using only one contract rotor, unless otherwise specified.

4.3.5.10 The vendor shall maintain a complete, detailed log of all final tests and shall prepare the required number of copies, including test curves and data, certified for correctness. All preliminary tests and mechanical checks shall be completed by the vendor before the purchaser's witnessed performance test.

• **4.3.5.11** The requirements of 4.3.5.11.1 through 4.3.5.11.6 shall be met before the performance test is performed. These items apply only to machines with oil lubricated bearings.

4.3.5.11.1 The contract shaft seals and bearings shall be used in the machine for the performance test. At the vendor's request, the purchaser may approve the use of substitute seals for reasons such as incompatibility of the contract seals with the test fluid. The acceptable level of leakage during testing shall be mutually agreed upon by the purchaser and the vendor.

4.3.5.11.2 All lubricating-oil and liquid-sealant pressures, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specified unit being tested. For circulating lubrication systems, oil flow rates for each bearing housing shall be measured.

4.3.5.11.3 For circulating lubrication systems, test-stand oil filtration shall be 10 microns nominal or better. Oil system components downstream of the filters shall be cleaned prior to the test in accordance with the vendor's criteria for field installation.

4.3.5.11.4 Bearings used in oil mist lubrication systems shall be prelubricated.

4.3.5.11.5 All joints and connections shall be checked for tightness, and any leaks shall be corrected.

4.3.5.11.6 All warning, protective, and control devices used during the test shall be checked, and adjustments shall be made as required.

• 4.3.6 OPTIONAL TESTS

The purchaser will specify in the inquiry or in the order whether any of the shop tests specified in 4.3.6.1 to 4.3.6.5 shall be performed.

• 4.3.6.1 Complete-Unit Test

Such components as compressors, gears, drivers, ring liquid system, and auxiliaries that make up a complete unit may be tested together as a complete unit. A separate auxiliary test may be performed with the purchaser's approval. When specified, torsional vibration measurements shall be made to verify the vendor's analysis. By agreement the complete-unit test may be combined with the mechanical running test of one or more of the individual components specified by the purchaser.

Table 5—Performance Tolerances

Variable	Tolerance (%)
Rated inlet volume	−0
Rated power	+4
Ring liquid flow rate	±10

Note: Standard industry tolerances are in accordance with HEI performance standards for liquid ring vacuum pumps. These are more liberal than the tolerances shown in Table 6, and if used could result in the selection of a smaller machine

• 4.3.6.2 Gear Test

The gear shall be tested with the machine unit during the mechanical running test.

• 4.3.6.3 Sound-Level Test

The sound-level test shall be performed in accordance with purchaser requirements.

• 4.3.6.4 Ring Stability Test

For variable speed machines a test agreed to between the purchaser and the vendor shall be conducted to establish the operating limits of liquid ring stability.

• 4.3.6.5 Auxiliary-Equipment Test

Auxiliary equipment such as control systems shall be tested in the vendor's shop. Details of the auxiliary equipment tests shall be developed jointly by the purchaser and the vendor.

4.4 Preparation for Shipment

• **4.4.1** Equipment shall be suitably prepared for the type of shipment specified. The preparation shall make the equipment capable of withstanding six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

4.4.2 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include that specified in 4.4.2.1 through 4.4.2.11.

4.4.2.1 Exterior surfaces, except for corrosion resistant materials and machined surfaces, shall be given at least one

coat of the manufacturer's standard non-lead and non-chromate paint.

4.4.2.2 Exterior machined surfaces, except for corrosion resistant materials, shall be coated with a suitable rust preventative.

4.4.2.3 Exposed shafts and shaft couplings shall be wrapped with waterproof, moldable waxed cloth or vapor-phase-inhibitor paper. The seams shall be sealed with oil-proof adhesive tape.

4.4.2.4 Bearing assemblies shall be fully protected from the entry of moisture and dirt. If vapor-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags must be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers, and bag locations shall be indicated by corrosion-resistant tags attached with stainless steel wire.

4.4.2.5 The interior of the equipment shall be clean; free from scale, welding spatter, and foreign objects; and sprayed or flushed with a suitable rust preventative that can be removed with solvent. The rust preventative shall be applied through all openings while the machine is slow-rolled.

4.4.2.6 Flanged openings shall be provided with metal closures at least 5 millimeters (3/16 inch) thick, with elastomer gaskets, and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures.

4.4.2.7 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 2.3.7.

• **4.4.2.8** When a spare rotor is purchased, it shall be prepared for unheated indoor storage for a period of at least three years. The rotor shall be treated with a rust preventative and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor. The rotor shall be crated for domestic or export shipment, as specified. A purchaser-approved resilient material 3.0 millimeters (1/8 inch) thick [not Tetrafluoroethylene (TFE) or Polytetrafluoroethylene (PTFE)] shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals.

4.4.2.9 Internal steel areas of bearing housings and carbon steel oil systems' auxiliary equipment such as reservoirs, vessels, and piping shall be coated with a suitable oil-soluble rust preventive.

4.4.2.10 Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be identified on boxed equipment.

4.4.2.11 The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

4.4.3 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 startup.

4.4.4 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. Service and connection designations shall be indicated.

4.4.5 One copy of the manufacturer's installation instructions shall be packed and shipped with the equipment.

4.4.6 Openings that have been beveled for welding shall be provided with closures designed to prevent entrance of foreign materials and damage to the bevel.

SECTION 5—VENDOR'S DATA

5.1 General

5.1.1 The information to be furnished by the vendor is specified in 5.2 and 5.3. The vendor shall complete and forward the Vendor Drawing and Data Requirements form (see Appendix G) to the addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the proposal or order, as well as the number and type of copies required by the purchaser.

5.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information:

a. Purchaser/user's corporate name.
b. Job/project number.
c. 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. Vendor's identifying proposal number, shop order number, serial number, or other reference required to identify return correspondence completely.

• **5.1.3** When specified, a coordination meeting shall be held, preferably at the vendor's plant, within four to six weeks after the purchase commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting which, as a minimum, will include review of the following items:

a. Purchase order, scope of supply, unit responsibility, and subvendor items.
b. Data sheets.
c. Applicable specifications and previously agreed upon exceptions.
d. Schedules for transmittal of data, production, and testing.
e. Quality assurance program and procedures.
f. Inspection, expediting, and testing.
g. Schematics and bills of material for auxiliary systems.
h. The physical orientation of the equipment, piping, and auxiliary systems.
i. Coupling and seal selections.
j. Bearing life.
k. Sizing criteria for auxiliary equipment.

5.2 Proposals

5.2.1 GENERAL

The vendor shall forward the original and the specified number of copies of the proposal to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 5.2.2 through 5.2.4 and a specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to enable the purchaser to evaluate any alternative designs proposed. All correspondence shall be clearly identified in accordance with 5.1.2.

5.2.2 DRAWINGS

5.2.2.1 The drawings described on the Vendor Drawing and Data Requirements form (see Appendix G) shall be included. As a minimum, the following preliminary data shall be furnished:

a. A general arrangement or outline drawing for each major skid or system showing estimated overall dimensions, and
b. Cross-sectional drawings showing details of the proposed equipment.
c. Piping and instrumentation diagrams (P&IDs) and lists of major components and instrumentation.

5.2.2.2 If "typical" drawings, schematics, and bills of material are used, they shall be marked up to show estimated weight and dimension data and to reflect the equipment and scope proposed.

5.2.3 TECHNICAL DATA

The following data shall be included in the proposal:

a. The purchaser's data sheet with complete vendor's information entered thereon and literature to fully describe details of the offering.
b. Completed purchaser's noise data sheet or the form from the appendix of API Standard 615.
c. The Vendor Drawing and Data Requirements form (see Appendix G) indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.
d. A schedule for shipment of the equipment, in weeks after receipt of the order.
e. A list of recommended spare parts for start-up and normal maintenance purposes.
f. A list of the special tools furnished for maintenance. The vendor shall state if metric items are included in the offering.
g. A statement of any special protection required for startup, operation, and periods of idleness under the site conditions specified on the data sheets. The list shall show the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply.
h. A complete tabulation of utility requirements, such as steam, water, electricity, air, and the nameplate power rating and operating power requirements of auxiliary drivers. (Approximate data shall be defined and clearly identified as such.)
i. A description of the tests and inspection procedures for materials, as required by 2.9.1.4.
j. A description of special requirements, specified in the purchaser's inquiry and as outlined in 2.9.1.3, 3.1.2.1, 3.1.2.2, 3.1.3.4, 3.1.4.2, 3.2.1.3, 3.2.4.1, 3.2.4.8.1, and 3.2.5.3.4.
k. A list of similar machines installed and operating under conditions analogous to those specified in the proposal.
l. Any startup, shutdown, or operating restrictions required to protect the integrity of the equipment.
m. List of vendor's proposed manufacturers for auxiliary equipment and instruments.
n. A description of proposed alarm and shutdown systems, when included in vendor's scope of supply.
o. Method of calculation used to convert from performance conditions on dry air and water to the specified operating conditions.

5.2.4 CURVES

5.2.4.1 The vendor shall provide performance curves to encompass the map of operations, with any limitations indicated thereon. Curves shall show volumetric capacity and required power as a function of discharge pressure (compres-

sors) or inlet pressure (vacuum pumps). Curves shall be based on dry air at 20°C (68°F) with water at 15°C (60°F) as the ring liquid. For variable speed applications, curves shall show the full range of operation from minimum speed to maximum continuous speed.

5.2.4.2 Estimated performance curves based on the specified conditions for the process gas and ring liquid shall be provided.

5.3 Contract Data

5.3.1 GENERAL

5.3.1.1 The contract information to be furnished by the vendor is specified in Appendix G. Each drawing, bill of material, and data sheet shall have a title block in the lower right hand corner that shows the date of certification, the reference to all identification data specified in 5.1.2, the revision number and date, and the title (see 5.3.2 and 5.3.3).

5.3.1.2 The purchaser will promptly review the vendor's data when he receives them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data have been reviewed, the vendor shall furnish certified copies in the quantity specified.

5.3.1.3 A complete list of vendor data shall be included with the first issue of major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of all data the vendor will furnish (see Appendix G).

5.3.2 DRAWINGS

The drawings furnished shall contain sufficient information so that with the drawings and the manuals specified in 5.3.6, the purchaser can properly install, operate, and maintain the ordered equipment. Drawings shall be clearly legible and shall be identified in accordance with 5.3.1.1. As a minimum, each drawing shall include the details for that drawing listed in Appendix G.

5.3.3 TECHNICAL DATA

Data shall be submitted in accordance with Appendix G and identified in accordance with 5.3.1.1. If any drawing comments or specification revisions necessitate a change to the data sheets, the vendor shall provide revised data which will be used by the purchaser to correct the data sheets for reissue as part of the order specifications.

5.3.4 PROGRESS REPORTS

The vendor shall submit progress reports to the purchaser at the interval specified on the Vendor Drawing and Data Requirements form (see Appendix G).

5.3.5 PARTS LISTS AND RECOMMENDED SPARES

5.3.5.1 The vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include manufacturer's unique part numbers, materials of construction, and delivery times. Materials shall be identified as specified in 2.9.1.3. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the purchaser may determine the interchangeability of the part with other equipment. Parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items shall be identified by the original manufacturer's name and part number.

5.3.5.2 The vendor shall indicate on the above parts lists which parts are recommended spares for startup and which parts are recommended for normal maintenance (see 5.2.3, Item f). The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified in 5.1.2.

5.3.6 INSTALLATION, OPERATION, AND MAINTENANCE MANUALS

5.3.6.1 The vendor shall provide sufficient written instructions and a list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. When specified, this information shall be compiled in a manual with a cover sheet containing all reference-identifying data required in 5.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. When specified, the manual shall be prepared for the specified installation; a typical manual is not acceptable.

5.3.6.2 Any special information required for proper installation design (such as special piping, foundation, and grouting procedures) that is not on the drawings shall be provided separate from the operating and maintenance instructions. This information shall be forwarded at a time mutually agreed upon in the order, but not later than the final issue of prints. This information shall also be included in the Installation, Operation, and Maintenance Manual.

5.3.6.3 Manuals shall be forwarded no more than two weeks after all of the specified tests have been successfully completed. When specified, manuals shall include a section that provides special instructions for operation at specified extreme environmental conditions, such as temperatures. As a minimum, the manual contents described in Appendix G shall also be included.

APPENDIX A—LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEETS

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____
Purch. Order No. _____ Date _____
Inquiry No. _____ By _____
Revision _____ Date _____

DESIGN, MANUFACTURE, INSPECTION, AND TESTING SHALL CONFORM TO SPECIFICATION: _____
INFORMATION TO BE COMPLETED: ○ BY PURCHASER ☐ BY MANUFACTURER ◘ BY PURCHASER OR MFR.

Applicable to: ○ Proposal ○ Purchase ○ As Built Service:
For: Unit: Site:
No. Systems Required: Size, No. Stages: Model:
Manufacturer: Vendor: Serial No.:

VACUUM PUMP OR COMPRESSOR DATA - GENERAL

No. Required:	Motor Item No.:	Turbine Item No.:
Item No.:	Motor Provided by:	Turbine Provided by:
No. Motor Driven:	Motor Mounted by:	Turbine Mounted by:
No. Turbine Driven:	Driver Data Sheet Nos.:	Turbine Data Sheet Nos.:

SYSTEM DESCRIPTION

○ Liquid Ring Vacuum Pump ○ Liquid Ring Compressor

LIQUID RING SYSTEM (Appendix D)

○ Once Through System
○ Partial Recirculation System
○ Total Recirculation System
Service: ○ Continuous ○ Intermittent Starts/Day:
○ Inlet System Volume: (m^3)
○ Required Evacuation Time: (min)

SITE AND UTILITY DATA

Location:
○ Indoor ○ Heated ○ Under Roof
○ Outdoor ○ Unheated ○ Partial Sides
○ Grade ○ Mezzanine ○
○ Electric Area Classification -
Class: Group: Div:
○ Winterization Reqd. ○ Tropicalization Reqd.

Steam Conditions	Drivers Press(kPa)	Drivers Temp (°C)	Heating Press(kPa)	Heating Temp (°C)
Min				
Max				

Electricity	Drivers	Heating	Control	Shutdown
Voltage				
Phase				
Hertz				

○ Elevation: (m); Barometer: (kPa abs)
○ Ambient Temp. Range - Max: Min: (°C)
○ Relative Humidity (%) - Max: Min:
Unusual Conditions - ○ Dust ○ Fumes
○ Corrosive Due to:
Cooling Water Temp. - Inlet: Norm: (°C)
Min: Max: Max Return: (°C)
○ Pressure- Normal: Design: (kPa)
Min Return: Max Allow DP: (kPa)
○ Water Source:
Instrument Air Press. - Max: Min: (kPa)

RING LIQUID

○ Type/Name of Liquid:
○ Supply Temperature-
Normal: Max: Min: (°C)
○ Supply Pressure: (kPa)
○ Vapor Pressure: (kPa abs)
○ Specific Gravity @ Max. Temperature:
○ Specific Heat: (kJ/kg °C)
○ Viscosity: cP @ (° C)
○ Max Viscosity @ Min Temperature: (cP)
○ Corrosive/Erosive Agent:
○ Chloride Concentration: (ppm)
○ H_2S Concentration: (ppm)
○ Toxic ○ Flammable ○ Other (3.5.2.11)
○ Ring Liquid Purge System (3.1.8):
☐ Circulation Rate: (m^3/hr)
☐ Make-up Rate: (m^3/hr)
☐ System Volume: (m^3)
☐ System Design Pressure: (kPa)
☐ Gas Solubility in Ring Liq.: kg/kg @ mmH_2O & °C

NOISE SPECIFICATION

○ Applicable to Machine:
○ Applicable to Neighborhood:
Acoustic Housing: ○ Yes ○ No

APPLICABLE SPECIFICATIONS

API 681, Liquid Ring Vacuum Pump and Compressor Systems for Refinery Service.
○ Governing Specification (If Different):

PAINTING (4.4.2)

○ Manufacturer's Standard
○ Unified, System Supplier's Standard:
○ Other:

SHIPMENT (4.4)

○ Domestic ○ Export ○ Export Boxing Reqd.
○ Outdoor Storage More Than Six Months (4.4.1)

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

OPERATING CONDITIONS						
(All Data On Per Unit Basis)	NORMAL	RATED	START UP	OTHER CONDITIONS A	OTHER CONDITIONS B	
○ Gas Handled						
○ m^3/hr (1.013 bar & 0 °C dry)						
○ Mass Flow (kg/min) (wet/dry)						
INLET CONDITIONS -						
○ Pressure (kPa)						
○ Temperature (°C)						
○ Relative Humidity (%)						
○ Molecular Weight (%)						
☐ Cp/Cv (K_1) or (Z_{avg})						
☐ Compressibility (Z_1) or (Z_{avg})						
☐ Inlet Volume Flow (m^3/hr) (wet/dry)						
DISCHARGE CONDITIONS -						
○ Pressure (kPa)						
○ Temperature (°C)						
☐ Cp/Cv (K_1) or (K_{avg})						
☐ Compressibility (Z_1) or (Z_{avg})						
☐ kW Required (All Losses Included)						
☐ kW Required at RV Setting						
☐ Speed (rpm)						
○ Guarantee Point						
☐ Performance Curve No.						

Gas Characteristics: ○ Toxic ○ Flammable ○ Other:

Gas Analysis: ○ mol % ○	MW	NORMAL	RATED	START UP	Other Cond. A	Other Cond. B	Remarks (2.9.1.13)
Air	28.966						
Oxygen	32.000						
Nitrogen	28.015						
Water Vapor	18.016						
Carbon Monoxide	28.010						
Carbon Dioxide	44.010						
Hydrogen Sulfide	34.076						
Hydrogen	2.016						(2.9.1.6) (2.9.1.9)
Methane	16.042						
Ethylene	28.062						
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							
Total							
Avg. Mol Wt.							

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

LIQUID RING MACHINE CONSTRUCTION FEATURES

SPEEDS

- ☐ Rotation, Viewed from Driven End
- ☐ Max. Continuous: ☐ Trip: rpm
- ☐ Minimum Stable Speed: rpm
- ☐ Lateral (Damped) Critical Speeds - rpm
  First: rpm: mode
- ○ Typical Lateral Analysis Required (2.7.1.7)
- ○ Undamped Stiffness Map Required
- ○ Train Torsional Analysis Reqd (2.7.1.12)
- ☐ First Torsional Critical Speed: rpm
- ☐ Vibration- Allowable Test Level (mils):

MATERIALS INSPECTION REQUIREMENTS (4.2.2)

- ○ Charpy Testing (2.9.4)
- ○ Radiography Required for:
- ○ Magnetic Particle Required for:
- ○ Liquid Penetrant Required for:

CASING

- ☐ Model: ☐ Casing Split:
- ☐ Material (2.9.2.5):
- ☐ Thickness: (mm); Corr. Allow.: (mm)
- ☐ Manifold Material:
- ☐ Port Plate/Cone Material:
- ☐ Max. Working Pressure: kPa
- ☐ Max. Design Pressure: kPa
- ☐ Test Press. (kPa) - Helium: Hydro:
- ☐ Oper. Temp. (°C) - Max: Min:
- ☐ Max. Casing Capacity: m^3
- ○ Casing Studs Required (2.2.6.2)
- ○ Casing Disassembly Jackscrews (2.2.7)
- ○ Spot Faced Mounting Holes (2.2.8)
- ○ Casing Vertical Jackscrews and Dowel Pilot Holes (2.2.9)
- ☐ Radiography Quality
- ○ System Relief Valve Set Pt. (2.2.2): kPa

ROTORS

- ☐ No.: ☐ Solid ☐ Hollow
- ☐ Diameters (mm):
- ☐ No. Vanes Per Rotor:
- Type: ☐ Open ☐ Closed ☐ Other:
- ☐ Type Fabrication:
- ☐ Material:
- ☐ Max. Yield Strength: kPa
- ☐ Brinnel Hardness - Max: Min:

SHAFT

- ☐ Material:
- ☐ Dia. - @ Rotor: @ Coupling: (mm)
- Shaft End: ☐ Tapered ☐ Cylindrical

SHAFT SLEEVES (2.5.5)

- ☐ At Shaft Seals - Material:

BEARING HOUSINGS

- ☐ Cast Iron ☐ Ductile Iron ☐ Steel
- Seals: ○ Lip Type ○ Labyrinth (2.8.2.5)
- ○ Vibration Probe Provisions (2.8.2.6)

BEARINGS AND LUBRICATION

Bearings -	Type	No.	Clearance
☐ Radial			
☐ Thrust			

Lubrication:

- ☐ Grease ☐ Flood ○ Ring Oil
- ☐ Flinger ☐ Purge Oil Mist ○ Oil Mist
- ○ Constant Level Oiler ○ Pressure
- ○ 1 1/2 NPS Minimum Oil Fill & Drain (2.8.2.4)
- ○ Oil Viscosity ISO Grade:
- ○ Oil Heater - ○ Electric ○ Steam
- ○ Oil Pressure to be Greater than Coolant Pressure

VIBRATION DETECTORS ○ See Attached API-670 Data Sht

- ○ Type: ○ API 670
- ○ Mfr: ☐ Model:
- ○ No. at each Shaft Bearing: ; Total No.:
- ○ Oscillator - Detectors Supplied by:
  ○ Mfr.: ☐ Model:
  Monitor Supplied by (3.2.4.6.):
  ○ Location: Enclosure:
  ○ Mfr: ☐ Model:
  ☐ Scale Range ☐ Alarm Set @ µm
  ○ Shutdown - ☐ Set @ µm ○ Time Delay: sec

AXIAL POSITION DETECTOR ○ See Attached API-670 Data Sht

- ○ Type: ○ No. Required:
- ○ Mfr: ☐ Model:
- ○ Oscillator - Demodulator Supplied by:
  ○ Manufacturer: ☐ Model:
  ○ Monitor Supplied by (3.2.4.6.):
  ○ Location: Enclosure:
  ○ Mfr: ☐ Model:
  ☐ Scale Range ☐ Alarm Set @ µm
  ○ Shutdown - ☐ Set @ µm ○ Time Delay sec

REMARKS:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

Connection	☐ No.	☐ Size	☐ Facing	☐ Rating	☐ Position	☐ Flanged Studded or Threaded (2.3)	○ Mating Ring & Gasket by Vendor (2.3.8.4)
System Inlet							
System Discharge							
Machine Inlet							
Machine Discharge							
Machine Drain							
Cooling Water							
Ring Liquid Inlet							
Vents							

☐ **ALLOW. FORCES AND MOMENTS ON LIQ. RING MACH.**

	Inlet		Discharge			
	Force	Mom't	Force	Mom't	Force	Mom't
	N	N-M	N	N-M	N	N-M
Axial						
Vertical						
Horiz. 90°						

	Force	Mom't	Force	Mom't	Force	Mom't
	N	N-M	N	N-M	N	N-M
Axial						
Vertical						
Horiz. 90°						

☐ **WEIGHTS (kgs)**

Liquid Ring Machine: Driver:

Separator:

Complete Unit:

Max. Maintenance:

Total Shipping:

☐ **SPACE REQUIREMENTS (MILLIMETERS)**

	Length	Width	Height
Complete Unit			
Liq. Ring Machine & Driver			
Separator Vessel			

COUPLINGS AND GUARDS

Coupling - Type:

Mfr/Model No.:

Furnished by:

☐ Spacer Length: Rating (kW/1000 rpm):

☐ Limited End Float Required (3.4.8)

Guard Type: ○ Fully Enclosed ○ Semi-Open ○ Non-spark

Furnished by:

○ Vendor Mount Half Coupling

○ Dynamically Balanced (3.4.7)

○ See Attached API - 671 Data Sheet

Lubricating Requirements:

○ Non-Lube ○ Grease ○ Other

☐ Belt Drive

☐ Belt Type/No.:

☐ Belt Mfr.:

☐ Belt Service Factor (3.5.1):

○ ISO Grade 6.3 Sheave Balance (3.5.4.7)

MOUNTING PLATES

○ Baseplates furnished by (3.6.1.1):

○ Machine and Driver ○ Complete System

○ Drip Rim (3.6.2.6) ○ Machine & Driver

○ For Complete System

○ Column Mounting (3.6.1.1) ○ Sub-Sole Plates Required

○ Continuously Grouted (3.6.1.1) ○ Leveling Pads (3.6.2.3)

☐ Stainless Steel Shim Thickness: millimeters

○ Primer for Epoxy Grout Required (3.6.1.2.5)

Type:

○ Machined Mounting Pads (3.6.2.9)

○ Non-Skid Decking (3.6.2.10)

○ Soleplates furnished by:

For: ○ Machine ○ Driver ○ Other:

☐ Thickness: millimeters

○ Sub-Sole Plates Required

○ Leveling (Chock) Blocks Required

☐ Stainless Steel Shim Thickness: millimeters

○ Primer for Epoxy Grout Required (3.6.1.2.5)

Type:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

MECHANICAL SEAL/PACKING

Seal Data -	Seal Construction -
○ Special Data Sheet:	○ No Sleeve
☐ API Material Class Code (Table H-4):	○ Pumping Ring
☐ Manufacturer:	○ Cartridge Mount
☐ Size and Type:	○ Hooked Sleeve or Non-Cartridge
☐ Manufacturer Code:	☐ Sleeve Material:
Packing Data -	☐ Gland Material:
☐ Manufacturer:	○ Auxiliary Seal Device:
☐ Type:	☐ Jacket Required
☐ Size and No. Rings:	Gland Taps:
☐ Packing Injection Required	☐ (F)lush ☐ (D)rain ☐ (B)arrier
☐ Flow: (m^3/hr) @ (kPa)	☐ (C)ooling ☐ (V)ent
☐ Lantern Ring:	☐ (H)eating ☐ (Q)uench
☐ Max. Sealing Pressure: (kPa)	☐ Fully Confined Gland Plate Gasket (2.6.11)

SEALING FLUIDS DATA

Seal Fluids-	Quench Fluid -
Note: If flush liquid is pumpage liquid (as in flush piping plans	○ Name of Fluid:
11 to 41), following flush liquid data is not required.	○ Flow Rate: (m^3/hr)
○ Temperature (°C) -	**Barrier Fluid -**
Supply: Min: Max:	○ Temperature (°C) -
○ Specific Gravity: @ °C	Supply: Min: Max:
○ Name of Fluid:	○ Specific Gravity: @ °C
○ Specific Heat: Kj/kg°C	○ Name of Fluid:
○ Vapor Pressure: (kPa abs) @ °C	○ Vapor Pressure: kPa abs @ °C
○ Toxic ○ Flammable ○ Other:	○ Toxic ○ Flammable ○ Other:
☐ Flow Rate (m^3/hr)- Max: Min:	☐ Flow Rate (m^3/hr)- Max: Min:
☐ Required Press. (kPa) - Max: Min:	☐ Required Press. (kPa) - Max: Min:
☐ Required Temp. (°C) - Max: Min:	☐ Required Temp. (°C) - Max: Min:

SEAL FLUSH PIPING

Plan:	○ Tubing	○ Carbon Steel	○ Type Tube Fittings:
	○ Pipe	○ Stainless Steel	○ Flow Indicator (Plan 52/53)
Auxiliary Plan:	○ Tubing	○ Carbon Steel	○ Heat Exchanger (Plan 52/53)
	○ Pipe	○ Stainless Steel	○ Pressure Switch (Plan 52/53)
Piping Assembly:	○ Threaded	○ Seal Welded	○ Pressure Guage (Plan 52/53)
○ Unions	○ Flanged	○ Socket Welded	○ Temperature Indicator (Plans 21, 22, 23, 32, 41)

COOLING WATER PIPING

○ Cooling Water Plan:		☐ Cooling Water Requirements -	Flow (m^3/hr)	Temp (°C)
○ Galvanized Piping Required	○ Inlet Valve	Seal Jacket/Bearing Housing		
○ Copper Tubing Required	○ Outlet Valve	Seal Heat Exchanger		
○ Stainless Steel Tubing Req'd	○ Sight Flow Indicators	Ring Liquid Cooler		
		Total Cooling Water		

PIPING SYSTEMS (3.7)

○ Vapor Inlet Piping (3.7.1.14)	○ LRVP Discharge Piping	○ Ring Liquid Piping
○ Pressure Control Valve	○ Check Valve ○ Block Valve	○ Automatic Shut-off Valve ○ Block Valves
○ Check Valve ○ Ejector	○ Relief Valve:	○ Make-up Control Valve ○ Make-up Piping
○ Block Valve	Set Press. kPa	○ Drain Piping ○ Drain Trap ○ Y-Type Strainer
○ Material: ○ Steel	○ Material: ○ Steel	○ Cartridge Type Filter ○ Duplex ○ Switch Valve
○ SS ○ Other:	○ SS ○ Other:	○ Material: ○ Steel ○ SS ○ Other:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

SEPARATOR (3.1.2)

O Inspection O Spot Radiography O Hydrotest

O Surface O Other:

O ASME Design with Stamp O ASME Design w/o Stamp

O Other:

O Corrosion Allowance (in.):

O Horizontal O Vertical

O Max. Allowable Liquid Carry-over: ppm

O Separator Liquid drain to at kPa

SEPARATOR MATERIALS

	Description	ASTM Number
O Shell		
O Heads		
O Demister		
O Nozzles		
O Flanges		
O Internals		
O Gaskets		

CONNECTIONS

	No.	Size	Rating/Facing/Type
Inlet			
Outlet			
Vent			
Drain			
Instruments			
Relief Valve			

All connections 38 mm and larger shall be flanged.

☐ Diameter (mm): ☐ Length (mm):

☐ Thickness - Shell / Head (mm):

☐ Clean Pressure Drop (Flange to Flange) (kPa):

☐ Gas Vertical Velocity (m/sec):

☐ Max. Allowable Working Pressure: kPa @ °C

☐ Minimum Design Metal Temperature: °C @ kPa

☐ Hydrotest Pressure (kPa):

☐ Support Method: ☐ Legs ☐ Skirt ☐ Saddles

Remarks:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

INSTRUMENTATION

○ Process Control Method:
- ○ Suction Throttling from ____ to ____ kPa
- ○ Speed Variation from ____ to ____ %
- ○ Discharge Blowoff to
- ○ Bypass from Discharge to Inlet

Signal- Source:

Type: ○ Electronic, Range ____ to ____ mA
○ Pneumatic: ____ kPa
○ Other:

Instrument Mounting:

○ Local Panel ○ Remote Panel
○ Locally (On Pipe or Equipment or on Local Gage Board)

INSTRUMENT SUPPLIERS

	Manufacturer	Size	Type
Pressure Gages			
Temperature Gages			
Level Gages			
Diff. Pressure Gages			
Pressure Switches			
Diff. Pressure Switches			
Temperature Switches			
Level Switches			
Control Valves			
Pressure Relief Valves			
Thermal Relief Valves			
Sight Flow Indicators			
Flow Switches			
Vibration Equipment			
Constant Level Oilers			
Solenoid Valves			
Annunciator		No. Points:	

PRESSURE GAGE REQUIREMENTS

	Locally Mounted	Local Panel	Remote Panel
1st Stage Inlet	○ □	○ □	○ □
2nd Stage Inlet	○ □	○ □	○ □
1st Stage Discharge	○ □	○ □	○ □
2nd Stage Discharge	○ □	○ □	○ □
1st Stage Liq. Ring Inlet	○ □	○ □	○ □
2nd Stage Liq. Ring Inlet	○ □	○ □	○ □
Other:	○ □	○ □	○ □

TEMPERATURE GAGE REQUIREMENTS

	Locally Mounted	Local Panel	Remote Panel
1st Stage Inlet	○ □	○ □	○ □
2nd Stage Inlet	○ □	○ □	○ □
1st Stage Discharge	○ □	○ □	○ □
2nd Stage Discharge	○ □	○ □	○ □
1st Stage Liq. Ring Inlet	○ □	○ □	○ □
2nd Stage Liq. Ring Inlet	○ □	○ □	○ □
Other:	○ □	○ □	○ □

ALARM & SHUTDOWN SWITCHES (3.2.5.1) (TABLE 2)

	Pre-Alarm	Shutdown		Pre-Alarm	Shutdown
○ High Gas Discharge Temp	○	○	○ High Ring Liquid Level	○	○
○ High Liq. Ring Outlet Temp	○	○	○ High Vibration	○	○
○ High Gas Outlet Pressure	○	○	○ Low Mech. Seal Fluid Press.	○	○
○ Low Ring Liquid Flow	○	○	○ Panel Purge Failure	○	○
○ Low Ring Liquid Level	○	○		○	○

Remarks:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

INSTRUMENTATION (Con't)

Switch Closures:

Alarm Contacts Shall: ○ Open ○ Close to Sound Alarm and be Normally: ○ Energized ○ De-Energized

Shutdown Contacts Shall: ○ Open ○ Close to Trip and be Normally: ○ Energized ○ De-Energized

Note: Normal Condition is when Compressor is in Operation

MISC. INSTRUMENTATION

- ○ Ring Liquid Sight Flow Indicator
- ○ Ring Liquid Level Gage
- ○ Vibration & Shaft Position Probes & Oscillator-Demodulators
- ○ Vibration & Shaft Position Readout Equipment
- Vibration Readout Location:
- ☐ Local Panel ☐ Separate Panel ☐ Control Room
- ○ Annunciator System
- ○ Panel & Annunciator Purge
- ○ Instrument Block Valves (Except Shutdown Instruments)
- ○ Instrument Block Valves for Shutdowns
- ○ Liquid Filled Pressure Gages
- ○ Alarm Horn & Acknowledgement Switch
- ○ Test Lamp Pushbutton
- ○ Permissive Start with Pilot Light
- ○ Pilot Light Incoming Circuits
- ○ Start-Stop Switches
- ○ Bearing Metal Temp. Sensors (2.8.2.7)
  - ○ Radial - Number: ○ Axial - Number:
- ○ Pre-Alarm & Shutdown Switches Shall be Separate
- ○ Electrical & Instrument Connections within the Confines of the Base Shall be Brought out to Terminal Boxes

MISCELLANEOUS

- ○ Anti-Fungal Protection & Corrosion Resistant Coatings for Electrical Materials (3.2.6.6)
- ○ Thermal Relief Valves
- ○ Ring Liquid Level Control Valve
- ○ Review of Purchaser's Piping (3.7.1.15) & Foundation
- ○ Review of Purchaser's Control System
- ○ Dynamic Rotor Balancing (ISO Grade:)
- ○ Special Skid Clearances or Safe Access Areas (2.1.7):
- ○ Air Run-in Required (2.1.14)
- ○ Spare Rotor Required (4.4.2.8)
- ○ Units of Measure (Dwgs., Nameplates, etc.) (2.10.3):
- ○ 5 Yr. Retention of Final Assembly Clearances (4.2.1.1.e)
- ○ Coordination Meeting Required (5.1.3)

INSPECTION & TESTING

	Req'd	Witness.	Obs.
Shop Inspection	○	○	○
Cleanliness (4.2.3.2)	○	○	○
QC Program Review (4.1.7)	○	○	○
Hydrostatic	○	○	○
Mech. Run-LR Machine	○	○	○
☐ Contract ☐ Idling ○ Max/Min Press. Ratio (2.7.2.3)			
Coupling Adaptor(s) ○ Max/Min Capacity (2.7.2.3)			
☐ Contract ☐ Shop	○	○	○
Probes Probes	○	○	○
Vibration Spectrum Plot (4.3.3.3.2)	○	○	○
Vibration Recording (4.3.3.3.3)	○	○	○
Cont. Plots of Speed, Vibration, Phase, Angle (4.3.3.5.2)	○	○	○
Seismic Vibration Data (4.3.3.5.4)	○	○	○
Critical Speed Verification (4.3.3.5.6)	○	○	○
4 Hr. Mech. Run (4.3.3.5.7)	○	○	○
Mech. Run Spare Rotor	○	○	○
Ring Stability Test (4.3.6.4)	○	○	○
Panel Functional Test	○	○	○
Gas Leak Test Disch. Press. (4.3.4)	○	○	○
○ Before ○ After Mechanical Run			
Performance Test	○	○	○
Contract Liquid Ring System	○	○	○
Complete Unit Test (4.2.3.3)	○	○	○
Hardness Tests (4.2.3.3)	○	○	○
Gear Test (4.3.6.2)	○	○	○
Sound Level Test (4.3.6.3)	○	○	○
○ Advance Notice Req'd: Days (4.1.4) (4.3.1.3)			
○ Inspection Checklist Req'd (4.1.6)			

☐ TOTAL UTILITY CONSUMPTION

Cooling Water:	m^3/hr
Steam, Normal:	kg/hr
Steam, Max.:	kg/hr
Instrument Air:	m^3/hr
kW (Driver):	kW
kW (Auxiliaries):	kW
Heaters:	kW
Purge (Air or Nitrogen):	m^3/hr

Remarks:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

1	**RING LIQUID COOLER**					
2	Duty: kW			Cooler Item Number:		
3	Supplier:			No. Units Required:		
4	Model Number:			Type:		
5	**OPERATING CONDITIONS**					
6		Shell Side		Tube Side		
7	○ Fluid					
8	☐ Total Flow (kg/hr)					
9	☐ Specific Gravity	@	°C	@	°C	
10	☐ Thermal Conductivity (Kj/kg x m^2 x °C)	@	°C	@	°C	
11	☐ Specific Heat (Kj/kg x °C)	@	°C	@	°C	
12	☐ Viscosity - SSU	@	°C	@	°C	
13	☐ Operating Temperatures (°C)	IN	OUT	IN	OUT	
14	Inlet Pressure (kPa)					
15	Inlet Velocity (m/sec)					
16	○ Pressure Drop (kPa)	ALLOW	CALC	ALLOW	CALC	
17	☐ Design Temperatures (°C)					
18	Pressure (kPa)	MIN	TEST	MIN	TEST	
19	Foul Resistance (m^2 x hr x °C / kJ)					
20	○ Min. Corrosion Allowance (mm)					
21	☐ Number of Passes per Shell					
22	**CONSTRUCTION DETAILS**					
23	☐ Total Area (1) (Sq. Meters):			☐ Shell: No. x ID.	x	mm
24	☐ LMTD:			☐ Tubes - No. per Shell:		
25	☐ Corrected MTD:			☐ O.D. x Length	(mm) x	(mm)
26	☐ Transfer Rate (Clean):			☐ Gauge - BWG:	(Avg., Min. Wall)	
27	☐ Transfer Rate (Service):			☐ Tube Pitch:	(mm) △ ○ ☐	
28	☐ Cross Baffles - Type:			☐ Removable Tube Bundle	☐ Yes	☐ No
29	○ Code Requirements: ○ ASME ○ TEMA:			○ Code Stamp:	☐ Yes	☐ No
30	☐ Weights (kg) - Each Bundle:			Bundle & Shell:		Full of Water:
31	☐ **NOZZLE SIZES**					

	Shell Side			Tube Side		
	No.	Size	Rating & Facing	No.	Size	Rating & Facing
Inlet						
Outlet						
Drain						
Vent						

38	○ **MATERIALS**		
39	Tubes:	Baffles:	
40	Tube Sheets:	Channel:	
41	Shell:	Channel Flanges:	
42	Shell Flanges:	Channel Nozzle Flanges:	
43	REMARKS: 1) Outside tube area excluding area in tube sheets.		
44	1) Units exempt from code stamp shell have longitudinal weld seams spot examined per Para. UW-52 of		
45	ASME code.		
46			
47			
48			
49			
50			
51			
52			

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job. No. _____ Item No. _____

Revision _____ Date _____

By _____

1	Pump Size and Model: Brg. Frame: Service:	
2	○ No. Pumps Req'd: No. Motors Req'd: Item No.: No. Turbines Req'd: Item No.:	
3	**○ OPERATING CONDITIONS - EACH PUMP**	**PERFORMANCE**
4	Liquid/Slurry:	Performance Curve No.:
5	PT °C Norm: Max: m^3/h at Norm: Rated:	RPM: NPSH (water):
6	Sp. Gr. at Norm PT: Total Head, m, Rated:	Eff.: % BkW Rated:
7	Vap. Press. at Norm. PT (kPa abs): Suct. Press. (kPa) Max: Rated:	Max. kW Rated Impeller:
8	Vis. at Norm. PT Pa·s: NPSHA, m:	Max. Head Rated:
9	Corr./Eros. caused by: Ph: Hyd. kW:	Max. Discharge Pressure (kPa):
10	Driver kw to be selected for Max. S.G.: & Max. Viscosity:	Min. Continuous m^3/h:
11		**SHOP TESTS**
12		○ Nonwit. Perf. ○ Wit. Perf.
13	**CONSTRUCTION:** ○ ASME B73.1M ○ ASME B73.2M	○ Nonwit. Hydro. ○ Wit. Hydro.
14	○ OTHER:	○ Nonwit. NPSH ○ Wit. NPSH
15	Pump Type: ○ Horiz. ○ Vert. In-Line ○ Coupled Motor Shaft	○ Nonwit. Vibration ○ Wit. Vibr.
16	○ Cradled Mnt.	○ Dismantle & Inspect After Test
17	Case Horizontal Mount: ☐ Foot ☐ Centerline	○ Other:
18	Vert. Mount: ☐ Motor Shaft ☐ Rigid Coupling ☐ Other:	
19	Split: ☐ Radial ☐ Axial Type Volute: ☐ Single ☐ Double	**PUMP MATERIALS**
20	Press: ☐ Max. Allow. (kPa) (°C) Hydro Test (kPa)	Casing:
21	Connect: ○ Drain ○ Gauge Suction ○ Gauge Discharge	Impeller:
22	Impeller Dia. Rated: Max.: Impeller Type:	Wear Rings:
23	Bearings Type: Radial: Thrust:	Shaft/Sleeve:
24	Lube: ☐ Oil ☐ Oil Mist ☐ Grease ☐ Grease for Life	Gland:
25	Coupling: Mfr.: Model: Guard: Oiler:	Gaskets:
26	Driver Half Mtd. By: ○ Pump Mfr. ○ Driver Mfr. ○ Purchaser	Baseplate:
27	Stuffing Box Cover: ☐ Standard ☐ Jacketed ☐ Seal Only	Coupling Guard:
28	○ Packing: ☐ Mfr. & Type: Size/No. of Rings:	Other:
29	Lantern Rings: ☐ Yes ☐ No	
30	○ Mech. Seal: ☐ Mfr. & Model Material Code:	**INSPECTION:** ○ Not Required
31	☐ Balanced ☐ Unbalanced ☐ Single ☐ Inside	○ In Process ○ Final
32	☐ Double ☐ Back to Back ☐ Tandem ☐ Outside	Days Notification Required:
33	☐ Cartridge ☐ Face to Face	**SOUND SPECIFICATION REQUIREMENTS**
34	**AUXILIARY PIPING (see Figs. A2 and A3 for Code)**	
35	☐ Stuf. Box Plan No.: ☐ C.W. Piping Plan No.:	
36	Total Cooling Water Req'd., m^3/h: ○ Sight F.I. Req'd.	
37	☐ Packing Cooling Injection Req'd., Total m^3/h (kPa)	
38	External Seal Flush Fluid m^3/h (kPa)	
39	Seal Quench Plan: Seal Quench Fluid:	**ADDITIONAL REQUIREMENTS/ COMMENTS**
40	**DRIVER:** ○ Motor ○ Turbine ○ Other, provided by:	
41	kW: RPM: Frame: Volts/Phase/Hertz:	
42	Mfr.: Bearings: Service Factor:	
43	Type: Insulation: Amps: FL LR	
44	Lube: Temp. Rise (°C): Encl.:	
45	Inlet Press.: Exhaust Press.: Steam Temp.: Water Rate:	
46	Other:	

47		Customer/User:	
48		Location:	
49		Customer P.O. No.:	
50		Items No(s).:	Equip. No(s).:
51	This data sheet is provided courtesy of	Factory Order No(s).:	Pump Serial No(s).:
52	the American Society of Mechanical	Issued By:	Date:
53	Engineers, ASME B73.2M–1991	Rev.:	Date:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job. No. _____ Item No. _____

Revision _____ Date _____

By _____

MOTOR DESIGN DATA	MOTOR DESIGN DATA (CONTINUED)
APPLICABLE SPECIFICATIONS:	VIBRATION:
○ NEMA	○ NEMA Standard ○
○	NOISE:
○	○ NEMA Standard ○
SITE DATA:	
Area: ○ Class Gr. Div. ○ Non-Hazardous	
○ Alt. (m) ○ Ambient Temp: Max. (°C) Min. (°C)	**ACCESSORY EQUIPMENT**
Unusual Conditions: ○ Dust ○ Fumes	○ Baseplate ○ Soleplate ○ Stator Shift
○ Other:	○ Mfr. Std Fans ○ Non-sparking Fans
DRIVE SYSTEM: ○ Direct Connected	○ D.C. EXCITATION
○ Gear	☐ kW Req'd.: Volts:
○ Other:	By: ○ Purchaser ○ Manufacturer
TYPE OF MOTOR:	Description:
○ Squirrel Cage Induction ○ NEMA Design	○ ENCLOSED COLLECTOR RINGS:
○ Synchronous	○ Purged: Medium Press. (kPa)
○ Power Factor Req'd.:	○ Explosion-Resistant Non-purged
Excitation: ○ Brushless ○ Slip Ring	○ Forced Ventilation
○ Field Discharge Resistor by Motor Mfr.	☐ m^3/h Press. Drop (mm) H_2O
○ Wound Rotor Induction	○ BEARING TEMP. DEVICES:
○	☐ Location:
ENCLOSURE:	☐ Description:
○ Class Group Div.	☐ Set @ (°C) for Alarm (°C) for Shutdown
○ TEFC, Severe Duty ○ Exp. Proof	○ SPACE HEATERS:
○ Weather Protected, Type:	☐ kW
○ TEWAC ○ TEIGF, Using Gas	○ Volts Phase Hertz
○ Double Wall Carbon Steel Tubes	○ Max. Sheath Temp.: (°C)
○ Water Supply: Press.: (kPa) Temp.: (°C)	WINDING TEMPERATURE DETECTOR:
☐ ○ Water Allow.: Δ P (kPa) & Temp., Rise: (°C)	○ Thermistors: No/Phase:
☐ ○ Water Side Min. Corr. Allow. (mm)	Type: ○ Pos. Temp. Coeff.
and Foul Factor:	○ Neg. Temp. Coeff.
○ (Air) (Gas) Supply Press. (kPa)	Temperature Switch: ○ Yes ○ No
○ Forced Ventilated	○ Resistance Temp. Detectors: No/Phase
○ Open-Drip Proof	○ Resistance Material
○ Open	○ Ohms
○	Selector Switch & Indicator by:
○	○ Purchaser
BASIC DATA:	○ Manufacturer
○ Volts Phase Hertz	☐ Max. Stator Winding Temperatures:
☐ Nameplate: kW Service Factor	(°C) for Alarm (°C) for Shutdown
○ Synchronous RPM	WINDING TEMP. DETECTOR & SPACE HEATER LEADS:
○ Insulation: Class Type	○ In Same Conduit Box
○ Temp. Rise: (°C) Above (°C) By:	○ In Separate Conduit Boxes
STARTING:	○ MOTOR ARRANGED FOR DIFFERENTIAL PROTECTION:
○ Full Voltage ○ Reduced Voltage %	○ Self-Balance Primary-Current Method
○ Loaded ○ Unloaded	○ C.T. Description:
○ Voltage Dip %	○ Extended Leads ☐ Length (m)

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job. No. _____ Item No. _____

Revision _____ Date _____

By _____

	ACCESSORY EQUIPMENT (CONTINUED)	MANUFACTURER'S DATA (CONTINUED)
1		
2	○ SURGE CAPACITORS:	Limit End Float to:
3	○ LIGHTNING ARRESTERS	Curves Req'd Based on Mtr. Saturation & Rated Volt:
4	○ C.T. FOR AMMETER	○ Speed vs Torque @ 100%, 90% & 80% rated Voltage:
5	○ Description:	○ Speed vs. Current @ 100%, 90% & 80% rated Voltage:
6	MAIN CONDUIT BOX SIZED FOR:	
7	○ Main Motor Leads ○ Type:	WEIGHT (kg):
8	○ Insulated ○ Non-Insulated	Net Weight: Shipping Weight:
9	○ C.T.'s for Diff. Protection (mounted by):	Rotor Weight: Max. Erection Wt.:
10	○ Surge Capacitors (mounted by):	Max. Maint. Wt. (Identify):
11	○ Lightning Arresters (mounted by):	DIMENSIONS (m):
12	○ C.T. for Ammeter (mounted by):	L: W: H:
13	○ Space for Stress Cones:	
14	○ AIR FILTERS.	
15	☐ Mfr.: ☐ Type:	
16		SHOP INSPECTION AND TESTS
17	MANUFACTURER'S DATA	Req'd. Witness
18	Manufacturer:	Shop Inspection: ○ ○
19	Frame No.: Full Load RPM (Ind.):	Testing per NEMA: ○ ○
20	Efficiency: F L. 3/4L 1/2L	Mfr. Std. Shop Tests: ○ ○
21	Pwr. Factor (Ind.) F.L. 3/4F 1/2L	Immersion Test: ○ ○
22	Curr. (Rated Volt.): Full Load Locked Rotor:	Special Tests (list below): ○ ○
23	Locked Rotor Power Factor:	○ ○
24	Locked Rotor w/Stand Time (cold start):	○ ○
25	Locked Rotor w/Stand Time (hot start).	○ ○
26	Torques (Ft.-Lb.). Full Load:	○ ○
27	Locked Rotor: Starting (Syn):	
28	Pull-Up (Ind.): Pull-In (Syn.):	PAINTING:
29	Breakdown (Ind.). Pull-Out (Syn.):	○ Manufacturer's Standard
30		○
31	Open Circuit Time Constant (Sec.):	○
32	Symmetrical Contribution to 3 Phase Terminal Fault:	
33	at 1/2 Cycle. at 3 Cycles:	SHIPMENT:
34	Reactances: Sub-Transient (X"D)	○ Domestic ○ Export ○ Export Boxing Req'd.
35	Transient (X'D) Synchronous (XD).	○ Outdoor Storage Over 3 Months
36	A.C. Stator Resistance. Ohms @ (°C)	○
37	Rated kVA:	○
38	kVA Inrush @ Full Volt. & Locked Rotor (Syn.): %	
39	kVA @ Full Voltage & 95% Speed: %	REMARKS:
40	Max. Line Curr in Stator on 1st Slip Cyc & Pull-Out (Syn.):	
41		
42	Acceleration Time (Mtr. only & Rated Volt.): Sec.	
43	Accel. Time (Mtr. & Load & 85% Rated Volt.). Sec.	
44	Rotor/Field Wk^2 & Mtr. Shaft ($kg\text{-}m^2$)	
45	No of Starts per Hour:	
46	Bearing. Type: Lubr	
47	Lube Oil Required m^3/h & (kPa)	
48	Total Shaft End Float.	
49		
50		

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Purch. Order No. _____ Date _____

Inquiry No. _____ By _____

Revision _____ Date _____

DESIGN, MANUFACTURE, INSPECTION, AND TESTING SHALL CONFORM TO SPECIFICATION: _____

INFORMATION TO BE COMPLETED: ○ BY PURCHASER ☐ BY MANUFACTURER ☐ BY PURCHASER OR MFR.

Applicable to: ○ Proposal ○ Purchase ○ As Built Service:

For: Unit: Site:

No. Systems Required: Size, No. Stages: Model:

Manufacturer: Vendor: Serial No.:

VACUUM PUMP OR COMPRESSOR DATA - GENERAL

No. Required:	Motor Item No.:	Turbine Item No.:
Item No.:	Motor Provided by:	Turbine Provided by:
No. Motor Driven:	Motor Mounted by:	Turbine Mounted by:
No. Turbine Driven:	Driver Data Sheet Nos.:	Turbine Data Sheet Nos.:

SYSTEM DESCRIPTION

○ Liquid Ring Vacuum Pump ○ Liquid Ring Compressor

LIQUID RING SYSTEM (Appendix D)

○ Once Through System

○ Partial Recirculation System

○ Total Recirculation System

Service: ○ Continuous ○ Intermittent Starts/Day:

○ Inlet System Volume: (ft^3)

○ Required Evacuation Time: (min)

SITE AND UTILITY DATA

Location:

○ Indoor ○ Heated ○ Under Roof

○ Outdoor ○ Unheated ○ Partial Sides

○ Grade ○ Mezzanine ○

○ Electric Area Classification -

Class: Group: Div:

○ Winterization Reqd. ○ Tropicalization Reqd.

Steam	Drivers		Heating	
Conditions	Press(psig)	Temp (°F)	Press(psig)	Temp (°F)
Min				
Max				

Electricity	Drivers	Heating	Control	Shutdown
Voltage				
Phase				
Hertz				

○ Elevation: (ft); Barometer: (psia)

○ Ambient Temp. Range - Max: Min: (°F)

○ Relative Humidity (%) - Max: Min:

Unusual Conditions - ○ Dust ○ Fumes

○ Corrosive Due to:

Cooling Water Temp. - Inlet: Norm: (°F)

Min: Max: Max Return: (°F)

○ Pressure- Normal: Design: (psig)

Min Return: Max Allow DP: (psi)

○ Water Source:

Instrument Air Press. - Max: Min: (psig)

RING LIQUID

○ Type/Name of Liquid:

○ Supply Temperature-

Normal: Max: Min: (°F)

○ Supply Pressure: (psig)

○ Vapor Pressure: (psig)

○ Specific Gravity @ Max. Temperature:

○ Specific Heat: (Btu/Lb °F)

○ Viscosity: cP @ (° F)

○ Max Viscosity @ Min Temperature: (cP)

○ Corrosive/Erosive Agent:

○ Chloride Concentration: (ppm)

○ H_2S Concentration: (ppm)

○ Toxic ○ Flammable ○ Other (3.5.2.11)

○ Ring Liquid Purge System (3.1.8):

☐ Circulation Rate: (gpm)

☐ Make-up Rate: (gpm)

☐ System Volume: (gal)

☐ System Design Pressure: (psig)

☐ Gas Solubility in Ring Liq.: lb/lb @ "H_2O & °F

NOISE SPECIFICATION

○ Applicable to Machine:

○ Applicable to Neighborhood:

Acoustic Housing: ○ Yes ○ No

APPLICABLE SPECIFICATIONS

API 681, Liquid Ring Vacuum Pump and Compressor Systems for Refinery Service.

○ Governing Specification (If Different):

PAINTING (4.4.2)

○ Manufacturer's Standard

○ Unified, System Supplier's Standard:

○ Other:

SHIPMENT (4.4)

○ Domestic ○ Export ○ Export Boxing Reqd.

○ Outdoor Storage More Than Six Months (4.4.1)

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

OPERATING CONDITIONS						
(All Data On Per Unit Basis)	NORMAL	RATED	START UP	OTHER CONDITIONS A	OTHER CONDITIONS B	
○ Gas Handled						
○ SCFM (14.7 psia & 60 °F dry)						
○ Mass Flow (Lb/min) (wet/dry)						
INLET CONDITIONS -						
○ Pressure (psia)						
○ Temperature (°F)						
○ Relative Humidity (%)						
○ Molecular Weight (%)						
□ Cp/Cv (K_1) or (Z_{avg})						
□ Compressibility (Z_1) or (Z_{avg})						
□ Inlet Volume Flow (cfm) (wet/dry)						
DISCHARGE CONDITIONS -						
○ Pressure (psia)						
○ Temperature (°F)						
□ Cp/Cv (K_1) or (K_{avg})						
□ Compressibility (Z_1) or (Z_{avg})						
□ BHP Required (All Losses Included)						
□ BHP Required at RV Setting						
□ Speed (rpm)						
○ Guarantee Point						
□ Performance Curve No.						

Gas Characteristics: ○ Toxic ○ Flammable ○ Other:

Gas Analysis: ○ mol % ○	MW	NORMAL	RATED	START UP	Other Cond. A	Other Cond. B	Remarks (2.9.1.13)
Air	28.966						
Oxygen	32.000						
Nitrogen	28.015						
Water Vapor	18.016						
Carbon Monoxide	28.010						
Carbon Dioxide	44.010						
Hydrogen Sulfide	34.076						
Hydrogen	2.016						(2.9.1.6) (2.9.1.9)
Methane	16.042						
Ethylene	28.062						
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							
Total							
Avg. Mol Wt.							

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

LIQUID RING MACHINE CONSTRUCTION FEATURES

SPEEDS

- ☐ Rotation, Viewed from Driven End
- ☐ Max. Continuous: ☐ Trip: rpm
- ☐ Minimum Stable Speed: rpm
- ☐ Lateral (Damped) Critical Speeds - rpm
  First: rpm: mode
- ○ Typical Lateral Analysis Required (2.7.1.7)
- ○ Undamped Stiffness Map Required
- ○ Train Torsional Analysis Reqd (2.7.1.12)
- ☐ First Torsional Critical Speed: rpm
- ☐ Vibration- Allowable Test Level (mils):

MATERIALS INSPECTION REQUIREMENTS (4.2.2)

- ○ Charpy Testing (2.9.4)
- ○ Radiography Required for:
- ○ Magnetic Particle Required for:
- ○ Liquid Penetrant Required for:

CASING

- ☐ Model: ☐ Casing Split:
- ☐ Material (2.9.2.5):
- ☐ Thickness: (in.); Corr. Allow.: (in.)
- ☐ Manifold Material:
- ☐ Port Plate/Cone Material:
- ☐ Max. Working Pressure: psig
- ☐ Max. Design Pressure: psig
- ☐ Test Press. (psig) - Helium: Hydro:
- ☐ Oper. Temp. (°F) - Max: Min:
- ☐ Max. Casing Capacity: icfm
- ○ Casing Studs Required (2.2.6.2)
- ○ Casing Disassembly Jackscrews (2.2.7)
- ○ Spot Faced Mounting Holes (2.2.8)
- ○ Casing Vertical Jackscrews and Dowel Pilot Holes (2.2.9)
- ☐ Radiography Quality
- ○ System Relief Valve Set Pt. (2.2.2): psig

ROTORS

- ☐ No.: ☐ Solid ☐ Hollow
- ☐ Diameters (in.):
- ☐ No. Vanes Per Rotor:
- Type: ☐ Open ☐ Closed ☐ Other:
- ☐ Type Fabrication:
- ☐ Material:
- ☐ Max. Yield Strength: psi
- ☐ Brinnel Hardness - Max: Min:

SHAFT

- ☐ Material:
- ☐ Dia. - @ Rotor: @ Coupling: (in.)
- Shaft End: ☐ Tapered ☐ Cylindrical

SHAFT SLEEVES (2.5.5)

- ☐ At Shaft Seals - Material:

BEARING HOUSINGS

- ☐ Cast Iron ☐ Ductile Iron ☐ Steel
- Seals: ○ Lip Type ○ Labyrinth (2.8.2.5)
- ○ Vibration Probe Provisions (2.8.2.6)

BEARINGS AND LUBRICATION

Bearings -	Type	No.	Clearance
☐ Radial			
☐ Thrust			

Lubrication:

- ☐ Grease ☐ Flood ○ Ring Oil
- ☐ Flinger ☐ Purge Oil Mist ○ Oil Mist
- ○ Constant Level Oiler ○ Pressure
- ○ 1/2 NPS Minimum Oil Fill & Drain (2.8.2.4)
- ○ Oil Viscosity ISO Grade:
- ○ Oil Heater - ○ Electric ○ Steam
- ○ Oil Pressure to be Greater than Coolant Pressure

VIBRATION DETECTORS ○ See Attached API-670 Data Sht

- ○ Type: ○ API 670
- ○ Mfr: ☐ Model:
- ○ No. at each Shaft Bearing: ; Total No.:
- ○ Oscillator - Detectors Supplied by:
  ○ Mfr.: ☐ Model:
  Monitor Supplied by (3.2.4.6.):
  ○ Location: Enclosure:
  ○ Mfr: ☐ Model:
  ☐ Scale Range ☐ Alarm Set @ mils
  ○ Shutdown - ☐ Set @ mils ○ Time Delay: sec

AXIAL POSITION DETECTOR ○ See Attached API-670 Data Sht

- ○ Type: ○ No. Required:
- ○ Mfr: ☐ Model:
- ○ Oscillator - Demodulator Supplied by:
  ○ Manufacturer: ☐ Model:
  ○ Monitor Supplied by (3.2.4.6.):
  ○ Location: Enclosure:
  ○ Mfr: ☐ Model:
  ☐ Scale Range ☐ Alarm Set @ mils
  ○ Shutdown - ☐ Set @ mils ○ Time Delay sec

REMARKS:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

Job No. _____ Item No. _____

Revision _____ Date _____

By _____

Connection	☐ No.	☐ Size	☐ Facing	☐ Rating	☐ Position	☐ Flanged Studded or Threaded (2.3)	○ Mating Ring & Gasket by Vendor (2.3.8.4)
System Inlet							
System Discharge							
Machine Inlet							
Machine Discharge							
Machine Drain							
Cooling Water							
Ring Liquid Inlet							
Vents							

☐ **ALLOW. FORCES AND MOMENTS ON LIQ. RING MACH.**

	Inlet		Discharge			
	Force	Mom't	Force	Mom't	Force	Mom't
	Lb	Ft-Lb	Lb	Ft-Lb	Lb	Ft-Lb
Axial						
Vertical						
Horiz. 90°						

	Force	Mom't	Force	Mom't	Force	Mom't
	Lb	Ft-Lb	Lb	Ft-Lb	Lb	Ft-Lb
Axial						
Vertical						
Horiz. 90°						

☐ **WEIGHTS (Lbs)**

Liquid Ring Machine: Driver:

Separator:

Complete Unit:

Max. Maintenance:

Total Shipping:

☐ **SPACE REQUIREMENTS (FT & INCHES)**

	Length	Width	Height
Complete Unit			
Liq. Ring Machine & Driver			
Separator Vessel			

COUPLINGS AND GUARDS

Coupling - Type:

Mfr/Model No.:

Furnished by:

☐ Spacer Length: Rating (Hp/100 rpm):

☐ Limited End Float Required (3.4.8)

Guard Type: ○ Fully Enclosed ○ Semi-Open ○ Non-spark

Furnished by:

○ Vendor Mount Half Coupling

○ Dynamically Balanced (3.4.7)

○ See Attached API - 671 Data Sheet

Lubricating Requirements:

○ Non-Lube ○ Grease ○ Other

☐ Belt Drive

☐ Belt Type/No.:

☐ Belt Mfr.:

☐ Belt Service Factor (3.5.1):

○ ISO Grade 6.3 Sheave Balance (3.5.4.7)

MOUNTING PLATES

○ Baseplates furnished by (3.6.1.1):

○ Machine and Driver ○ Complete System

○ Drip Rim (3.6.2.6) ○ Machine & Driver

○ For Complete System

○ Column Mounting (3.6.1.1) ○ Sub-Sole Plates Required

○ Continuously Grouted (3.6.1.1) ○ Leveling Pads (3.6.2.3)

☐ Stainless Steel Shim Thickness: inches

○ Primer for Epoxy Grout Required (3.6.1.2.5)

Type:

○ Machined Mounting Pads (3.6.2.9)

○ Non-Skid Decking (3.6.2.10)

○ Soleplates furnished by:

For: ○ Machine ○ Driver ○ Other:

☐ Thickness: inches

○ Sub-Sole Plates Required

○ Leveling (Chock) Blocks Required

☐ Stainless Steel Shim Thickness: inches

○ Primer for Epoxy Grout Required (3.6.1.2.5)

Type:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

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MECHANICAL SEAL/PACKING

Seal Data -	Seal Construction -
○ Special Data Sheet:	○ No Sleeve
☐ API Material Class Code (Table H-4):	○ Pumping Ring
☐ Manufacturer:	○ Cartridge Mount
☐ Size and Type:	○ Hooked Sleeve or Non-Cartridge
☐ Manufacturer Code:	☐ Sleeve Material:
Packing Data -	☐ Gland Material:
☐ Manufacturer:	○ Auxiliary Seal Device:
☐ Type:	☐ Jacket Required
☐ Size and No. Rings:	Gland Taps:
☐ Packing Injection Required	☐ (F)lush ☐ (D)rain ☐ (B)arrier
☐ Flow: (gpm) @ (psig)	☐ (C)ooling ☐ (V)ent
☐ Lantern Ring:	☐ (H)eating ☐ (Q)uench
☐ Max. Sealing Pressure: (psig)	☐ Fully Confined Gland Plate Gasket (2.6.11)

SEALING FLUIDS DATA

Seal Fluids-	Quench Fluid -
Note: If flush liquid is pumpage liquid (as in flush piping plans	○ Name of Fluid:
11 to 41), following flush liquid data is not required.	○ Flow Rate: (gpm)
○ Temperature (°F) -	**Barrier Fluid -**
Supply: Min: Max:	○ Temperature (°F) -
○ Specific Gravity: @ °F	Supply: Min: Max:
○ Name of Fluid:	○ Specific Gravity: @ °F
○ Specific Heat: Btu/Lb°F	○ Name of Fluid:
○ Vapor Pressure: (psia) @ °F	○ Vapor Pressure: psia @ °F
○ Toxic ○ Flammable ○ Other:	○ Toxic ○ Flammable ○ Other:
☐ Flow Rate (gpm) - Max: Min:	☐ Flow Rate (gpm) - Max: Min:
☐ Required Press. (psig) - Max: Min:	☐ Required Press. (psig) - Max: Min:
☐ Required Temp. (°F) - Max: Min:	☐ Required Temp. (°F) - Max: Min:

SEAL FLUSH PIPING

Plan:	○ Tubing	○ Carbon Steel	○ Type Tube Fittings:
	○ Pipe	○ Stainless Steel	○ Flow Indicator (Plan 52/53)
Auxiliary Plan:	○ Tubing	○ Carbon Steel	○ Heat Exchanger (Plan 52/53)
	○ Pipe	○ Stainless Steel	○ Pressure Switch (Plan 52/53)
Piping Assembly:	○ Threaded	○ Seal Welded	○ Pressure Guage (Plan 52/53)
○ Unions	○ Flanged	○ Socket Welded	○ Temperature Indicator (Plans 21, 22, 23, 32, 41)

COOLING WATER PIPING

○ Cooling Water Plan:	☐ Cooling Water Requirements -	Flow (gpm)	Temp (°F)
○ Galvanized Piping Required ○ Inlet Valve	Seal Jacket/Bearing Housing		
○ Copper Tubing Required ○ Outlet Valve	Seal Heat Exchanger		
○ Stainless Steel Tubing Req'd ○ Sight Flow Indicators	Ring Liquid Cooler		
	Total Cooling Water		

PIPING SYSTEMS (3.7)

○ Vapor Inlet Piping (3.7.1.14)	○ LRVP Discharge Piping	○ Ring Liquid Piping
○ Pressure Control Valve	○ Check Valve ○ Block Valve	○ Automatic Shut-off Valve ○ Block Valves
○ Check Valve ○ Ejector	○ Relief Valve:	○ Make-up Control Valve ○ Make-up Piping
○ Block Valve	Set Press. psig	○ Drain Piping ○ Drain Trap ○ Y-Type Strainer
○ Material: ○ Steel	○ Material: ○ Steel	○ Cartridge Type Filter ○ Duplex ○ Switch Valve
○ SS ○ Other:	○ SS ○ Other:	○ Material: ○ Steel ○ SS ○ Other:

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SEPARATOR (3.1.2)

O Inspection O Spot Radiography O Hydrotest

O Surface O Other:

O ASME Design with Stamp O ASME Design w/o Stamp

O Other:

O Corrosion Allowance (in.):

O Horizontal O Vertical

O Max. Allowable Liquid Carry-over: ppm

O Separator Liquid drain to at psig

SEPARATOR MATERIALS

	Description	ASTM Number
O Shell		
O Heads		
O Demister		
O Nozzles		
O Flanges		
O Internals		
O Gaskets		

CONNECTIONS

	No.	Size	Rating/Facing/Type
Inlet			
Outlet			
Vent			
Drain			
Instruments			
Relief Valve			

All connections 1-1/2" and larger shall be flanged.

☐ Diameter (in.): ☐ Length (in.):

☐ Thickness - Shell / Head (in.):

☐ Clean Pressure Drop (Flange to Flange) (psi):

☐ Gas Vertical Velocity (ft/sec):

☐ Max. Allowable Working Pressure: psig @ °F

☐ Minimum Design Metal Temperature: °F @ psig

☐ Hydrotest Pressure (psig):

☐ Support Method: ☐ Legs ☐ Skirt ☐ Saddles

Remarks:

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INSTRUMENTATION

○ Process Control Method:	**Signal-** Source:
○ Suction Throttling from ____ to ____ psia	Type: ○ Electronic, Range ____ to ____ mA
○ Speed Variation from ____ to ____ %	○ Pneumatic: ____ psig
○ Discharge Blowoff to	○ Other:
○ Bypass from Discharge to Inlet	**Instrument Mounting:**
	○ Local Panel ○ Remote Panel
	○ Locally (On Pipe or Equipment or on Local Gage Board)

INSTRUMENT SUPPLIERS

	Manufacturer	Size	Type
Pressure Gages			
Temperature Gages			
Level Gages			
Diff. Pressure Gages			
Pressure Switches			
Diff. Pressure Switches			
Temperature Switches			
Level Switches			
Control Valves			
Pressure Relief Valves			
Thermal Relief Valves			
Sight Flow Indicators			
Flow Switches			
Vibration Equipment			
Constant Level Oilers			
Solenoid Valves			
Annunciator		No. Points:	

PRESSURE GAGE REQUIREMENTS

	Locally Mounted	Local Panel	Remote Panel
1st Stage Inlet	○ □	○ □	○ □
2nd Stage Inlet	○ □	○ □	○ □
1st Stage Discharge	○ □	○ □	○ □
2nd Stage Discharge	○ □	○ □	○ □
1st Stage Liq. Ring Inlet	○ □	○ □	○ □
2nd Stage Liq. Ring Inlet	○ □	○ □	○ □
Other:	○ □	○ □	○ □

TEMPERATURE GAGE REQUIREMENTS

	Locally Mounted	Local Panel	Remote Panel
1st Stage Inlet	○ □	○ □	○ □
2nd Stage Inlet	○ □	○ □	○ □
1st Stage Discharge	○ □	○ □	○ □
2nd Stage Discharge	○ □	○ □	○ □
1st Stage Liq. Ring Inlet	○ □	○ □	○ □
2nd Stage Liq. Ring Inlet	○ □	○ □	○ □
Other:	○ □	○ □	○ □

ALARM & SHUTDOWN SWITCHES (3.2.5.1) (TABLE 2)

	Pre-Alarm	Shutdown		Pre-Alarm	Shutdown
○ High Gas Discharge Temp	○	○	○ High Ring Liquid Level	○	○
○ High Liq. Ring Outlet Temp	○	○	○ High Vibration	○	○
○ High Gas Outlet Pressure	○	○	○ Low Mech. Seal Fluid Press.	○	○
○ Low Ring Liquid Flow	○	○	○ Panel Purge Failure	○	○
○ Low Ring Liquid Level	○	○		○	○

Remarks:

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INSTRUMENTATION (Con't)

Switch Closures:

Alarm Contacts Shall: ○ Open ○ Close to Sound Alarm and be Normally: ○ Energized ○ De-Energized

Shutdown Contacts Shall: ○ Open ○ Close to Trip and be Normally: ○ Energized ○ De-Energized

Note: Normal Condition is when Compressor is in Operation

MISC. INSTRUMENTATION

- ○ Ring Liquid Sight Flow Indicator
- ○ Ring Liquid Level Gage
- ○ Vibration & Shaft Position Probes & Oscillator-Demodulators
- ○ Vibration & Shaft Position Readout Equipment

Vibration Readout Location:

☐ Local Panel ☐ Separate Panel ☐ Control Room

- ○ Annunciator System
- ○ Panel & Annunciator Purge
- ○ Instrument Block Valves (Except Shutdown Instruments)
- ○ Instrument Block Valves for Shutdowns
- ○ Liquid Filled Pressure Gages
- ○ Alarm Horn & Acknowledgement Switch
- ○ Test Lamp Pushbutton
- ○ Permissive Start with Pilot Light
- ○ Pilot Light Incoming Circuits
- ○ Start-Stop Switches
- ○ Bearing Metal Temp. Sensors (2.8.2.7)
  - ○ Radial - Number: ○ Axial - Number:
- ○ Pre-Alarm & Shutdown Switches Shall be Separate
- ○ Electrical & Instrument Connections within the Confines of the Base Shall be Brought out to Terminal Boxes

MISCELLANEOUS

- ○ Anti-Fungal Protection & Corrosion Resistant Coatings for Electrical Materials (3.2.6.6)
- ○ Thermal Relief Valves
- ○ Ring Liquid Level Control Valve
- ○ Review of Purchaser's Piping (3.7.1.15) & Foundation
- ○ Review of Purchaser's Control System
- ○ Dynamic Rotor Balancing (ISO Grade:)
- ○ Special Skid Clearances or Safe Access Areas (2.1.7):
- ○ Air Run-in Required (2.1.14)
- ○ Spare Rotor Required (4.4.2.8)
- ○ Units of Measure (Dwgs., Nameplates, etc.) (2.10.3):
- ○ 5 Yr. Retention of Final Assembly Clearances (4.2.1.1.e)
- ○ Coordination Meeting Required (5.1.3)

INSPECTION & TESTING

	Req'd	Witness.	Obs.
Shop Inspection	○	○	○
Cleanliness (4.2.3.2)	○	○	○
QC Program Review (4.1.7)	○	○	○
Hydrostatic	○	○	○
Mech. Run-LR Machine	○	○	○
☐ Contract ☐ Idling ○ Max/Min Press. Ratio (2.7.2.3)			
Coupling Adaptor(s) ○ Max/Min Capacity (2.7.2.3)			
☐ Contract ☐ Shop	○	○	○
Probes Probes	○	○	○
Vibration Spectrum Plot (4.3.3.3.2)	○	○	○
Vibration Recording (4.3.3.3.3)	○	○	○
Cont. Plots of Speed, Vibration, Phase, Angle (4.3.3.5.2)	○	○	○
Seismic Vibration Data (4.3.3.5.4)	○	○	○
Critical Speed Verification (4.3.3.5.6)	○	○	○
4 Hr. Mech. Run (4.3.3.5.7)	○	○	○
Mech. Run Spare Rotor	○	○	○
Ring Stability Test (4.3.6.4)	○	○	○
Panel Functional Test	○	○	○
Gas Leak Test Disch. Press. (4.3.4)	○	○	○
○ Before ○ After Mechanical Run			
Performance Test	○	○	○
Contract Liquid Ring System	○	○	○
Complete Unit Test (4.2.3.3)	○	○	○
Hardness Tests (4.2.3.3)	○	○	○
Gear Test (4.3.6.2)	○	○	○
Sound Level Test (4.3.6.3)	○	○	○

○ Advance Notice Req'd: Days (4.1.4) (4.3.1.3)

○ Inspection Checklist Req'd (4.1.6)

☐ TOTAL UTILITY CONSUMPTION

Cooling Water:	gpm
Steam, Normal:	Lbs/Hr
Steam, Max.:	Lbs/Hr
Instrument Air:	scfm
Hp (Driver):	Hp
Hp (Auxiliaries):	Hp
Heaters:	kW
Purge (Air or Nitrogen):	scfm

Remarks:

LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

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1	**RING LIQUID COOLER**						
2	Duty: Btu/hr			Cooler Item Number:			
3	Supplier:			No. Units Required:			
4	Model Number:			Type:			
5	**OPERATING CONDITIONS**						
6		Shell Side		Tube Side			
7	○ Fluid						
8	☐ Total Flow (Lbs/hr)						
9	☐ Specific Gravity	@ °F		@ °F			
10	☐ Thermal Conductivity (Btu/hr x Sq. Ft. x °F)	@ °F		@ °F			
11	☐ Specific Heat (Btu/lb x °F)	@ °F		@ °F			
12	☐ Viscosity - SSU	@ °F		@ °F			
13	☐ Operating Temperatures (°F)	IN	OUT	IN	OUT		
14	Inlet Pressure (psig)						
15	Inlet Velocity (ft/sec)						
16	○ Pressure Drop (psi)	ALLOW	CALC	ALLOW	CALC		
17	☐ Design Temperatures (°F)						
18	Pressure (psig)	MIN	TEST	MIN	TEST		
19	Foul Resistance (ft^2 x hr x °F/Btu)						
20	○ Min. Corrosion Allowance (inches)						
21	☐ Number of Passes per Shell						
22	**CONSTRUCTION DETAILS**						
23	☐ Total Area (1) (Sq. Ft):			☐ Shell: No. x ID. x Inches			
24	☐ LMTD:			☐ Tubes - No. per Shell:			
25	☐ Corrected MTD:			☐ O.D. x Length (In.) x (In.)			
26	☐ Transfer Rate (Clean):			☐ Gauge - BWG: (Avg., Min. Wall)			
27	☐ Transfer Rate (Service):			☐ Tube Pitch: (In.) △ ○ ☐			
28	☐ Cross Baffles - Type:			☐ Removable Tube Bundle ☐ Yes ☐ No			
29	○ Code Requirements: ○ ASME ○ TEMA:			○ Code Stamp: ☐ Yes ☐ No			
30	☐ Weights (lbs) - Each Bundle:			Bundle & Shell:		Full of Water:	
31	☐ **NOZZLE SIZES**						
32		Shell Side			Tube Side		
33		No.	Size	Rating & Facing	No.	Size	Rating & Facing
34	Inlet						
35	Outlet						
36	Drain						
37	Vent						
38	○ **MATERIALS**						
39	Tubes:			Baffles:			
40	Tube Sheets:			Channel:			
41	Shell:			Channel Flanges:			
42	Shell Flanges:			Channel Nozzle Flanges:			
43	REMARKS: 1) Outside tube area excluding area in tube sheets.						
44	1) Units exempt from code stamp shell have longitudinal weld seams spot examined per Para. UW-52 of						
45	ASME code.						
46							
47							
48							
49							
50							
51							
52							

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LIQUID RING VACUUM PUMP AND COMPRESSOR SYSTEM DATA SHEET

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1	Pump Size and Model: Brg. Frame: Service:	
2	○ No. Pumps Req'd: No. Motors Req'd: Item No.: No. Turbines Req'd: Item No.:	
3	**○ OPERATING CONDITIONS - EACH PUMP**	**PERFORMANCE**
4	Liquid/Slurry:	Performance Curve No.:
5	PT °F Norm: Max: US GPM at Norm: Rated:	RPM: NPSH (water):
6	Sp. Gr. at Norm PT: Total Head, Ft. Rated:	Eff.: % BHP Rated:
7	Vap. Press. at Norm. PT (psia): Suct. Press. (psig) Max: Rated:	Max. BHP Rated Impeller:
8	Vis. at Norm. PT cP: NPSHA, Ft.:	Max. Head Rated:
9	Corr./Eros. caused by: Ph: Hyd. Hp:	Max. Discharge Pressure psig:
10	Driver Hp to be selected for Max. S.G.: & Max. Viscosity:	Min. Continuous gpm:
11		**SHOP TESTS**
12		○ Nonwit. Perf. ○ Wit. Perf.
13	**CONSTRUCTION:** ○ ASME B73.1M ○ ASME B73.2M	○ Nonwit. Hydro. ○ Wit. Hydro.
14	○ OTHER:	○ Nonwit. NPSH ○ Wit. NPSH
15	Pump Type: ○ Horiz. ○ Vert. In-Line ○ Coupled Motor Shaft	○ Nonwit. Vibration ○ Wit. Vibr.
16	○ Cradled Mnt.	○ Dismantle & Inspect After Test
17	Case Horizontal Mount: ☐ Foot ☐ Centerline	○ Other:
18	Vert. Mount: ☐ Motor Shaft ☐ Rigid Coupling ☐ Other:	
19	Split: ☐ Radial ☐ Axial Type Volute: ☐ Single ☐ Double	**PUMP MATERIALS**
20	Press: ☐ Max. Allow. (psig) (°F) Hydro Test (psig)	Casing:
21	Connect: ○ Drain ○ Gauge Suction ○ Gauge Discharge	Impeller:
22	Impeller Dia. Rated: Max.: Impeller Type:	Wear Rings:
23	Bearings Type: Radial: Thrust:	Shaft/Sleeve:
24	Lube: ☐ Oil ☐ Oil Mist ☐ Grease ☐ Grease for Life	Gland:
25	Coupling: Mfr.: Model: Guard: Oiler:	Gaskets:
26	Driver Half Mtd. By: ○ Pump Mfr. ○ Driver Mfr. ○ Purchaser	Baseplate:
27	Stuffing Box Cover: ☐ Standard ☐ Jacketed ☐ Seal Only	Coupling Guard:
28	○ Packing: ☐ Mfr. & Type: Size/No. of Rings:	Other:
29	Lantern Rings: ☐ Yes ☐ No	
30	○ Mech. Seal: ☐ Mfr. & Model Material Code:	**INSPECTION:** ○ Not Required
31	☐ Balanced ☐ Unbalanced ☐ Single ☐ Inside	○ In Process ○ Final
32	☐ Double ☐ Back to Back ☐ Tandem ☐ Outside	Days Notification Required:
33	☐ Cartridge ☐ Face to Face	**SOUND SPECIFICATION REQUIREMENTS**
34	**AUXILIARY PIPING (see Figs. A2 and A3 for Code)**	
35	☐ Stuf. Box Plan No.: ☐ C.W. Piping Plan No.:	
36	Total Cooling Water Req'd. (gpm): ○ Sight F. I. Req'd.	
37	☐ Packing Cooling Injection Req'd., Total (gpm) (psig)	
38	External Seal Flush Fluid (gpm) (psig)	
39	Seal Quench Plan: Seal Quench Fluid:	**ADDITIONAL REQUIREMENTS/ COMMENTS**
40	**DRIVER:** ○ Motor ○ Turbine ○ Other, provided by:	
41	HP: RPM: Frame: Volts/Phase/Hertz:	
42	Mfr. Bearings: Service Factor:	
43	Type: Insulation: Amps: FL LR	
44	Lube: Temp. Rise (°F): Encl.:	
45	Inlet Press.: Exhaust Press.: Steam Temp.: Water Rate:	
46	Other:	

47		Customer/User:	
48		Location:	
49		Customer P.O. No.:	
50		Items No(s).:	Equip. No(s).:
51	This data sheet is provided courtesy of	Factory Order No(s).:	Pump Serial No(s).:
52	the American Society of Mechanical	Issued By:	Date:
53	Engineers, ASME B73.2M–1991	Rev.:	Date:

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MOTOR DESIGN DATA	MOTOR DESIGN DATA (CONTINUED)
APPLICABLE SPECIFICATIONS:	VIBRATION:
○ NEMA	○ NEMA Standard ○
○	NOISE:
○	○ NEMA Standard ○
SITE DATA:	
Area: ○ Class Gr. Div. ○ Non-Hazardous	
○ Alt. Ft. ○ Ambient Temp: Max. (°F) Min. (°F)	**ACCESSORY EQUIPMENT**
Unusual Conditions: ○ Dust ○ Fumes	○ Baseplate ○ Soleplate ○ Stator Shift
○ Other:	○ Mfr. Std Fans ○ Non-sparking Fans
DRIVE SYSTEM: ○ Direct Connected	○ D.C. EXCITATION
○ Gear	☐ kW Req'd.: Volts:
○ Other:	By: ○ Purchaser ○ Manufacturer
TYPE OF MOTOR:	Description:
○ Squirrel Cage Induction ○ NEMA Design	○ ENCLOSED COLLECTOR RINGS:
○ Synchronous	○ Purged: Medium Press. (psig)
○ Power Factor Req'd.:	○ Explosion-Resistant Non-purged
Excitation: ○ Brushless ○ Slip Ring	○ Forced Ventilation
○ Field Discharge Resistor by Motor Mfr	☐ cfm Press. Drop In. H_2O
○ Wound Rotor Induction	○ BEARING TEMP. DEVICES:
○	☐ Location:
ENCLOSURE:	☐ Description:
○ Class Group Div.	☐ Set @ (°F) for Alarm (°F) for Shutdown
○ TEFC, Severe Duty ○ Exp. Proof	○ SPACE HEATERS:
○ Weather Protected, Type:	☐ kW
○ TEWAC ○ TEIGF, Using Gas	○ Volts Phase Hertz
○ Double Wall Carbon Steel Tubes	○ Max. Sheath Temp.: (°F)
○ Water Supply: Press.: (psig) Temp.: (°F)	WINDING TEMPERATURE DETECTOR:
☐ ○ Water Allow.. Δ P (psi) & Temp., Rise: (°F)	○ Thermistors: No/Phase:
☐ ○ Water Side Min. Corr. Allow (In)	Type: ○ Pos. Temp. Coeff.
and Foul Factor:	○ Neg. Temp. Coeff.
○ (Air) (Gas) Supply Press. (psig)	Temperature Switch: ○ Yes ○ No
○ Forced Ventilated	○ Resistance Temp. Detectors: No/Phase
○ Open-Drip Proof	○ Resistance Material
○ Open	○ Ohms
○	Selector Switch & Indicator by:
○	○ Purchaser
BASIC DATA:	○ Manufacturer
○ Volts Phase Hertz	☐ Max. Stator Winding Temperatures:
☐ Nameplate: Hp Service Factor	(°F) for Alarm (°F) for Shutdown
○ Synchronous RPM	WINDING TEMP. DETECTOR & SPACE HEATER LEADS:
○ Insulation: Class Type	○ In Same Conduit Box
○ Temp. Rise: (°F) Above (°F) By:	○ In Separate Conduit Boxes
STARTING:	○ MOTOR ARRANGED FOR DIFFERENTIAL PROTECTION:
○ Full Voltage ○ Reduced Voltage %	○ Self-Balance Primary-Current Method
○ Loaded ○ Unloaded	○ C.T. Description:
○ Voltage Dip %	○ Extended Leads ☐ Length (Ft.)

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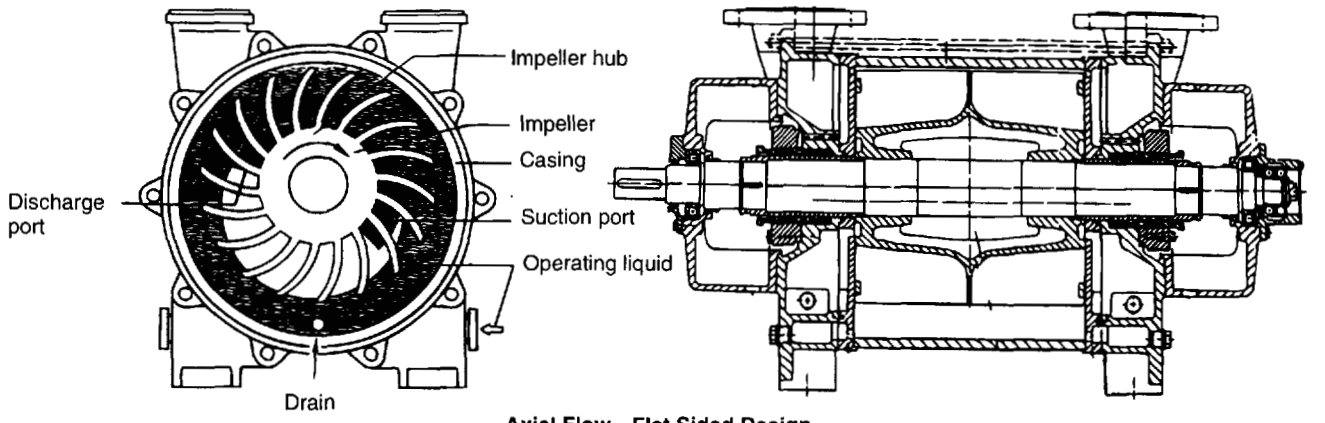
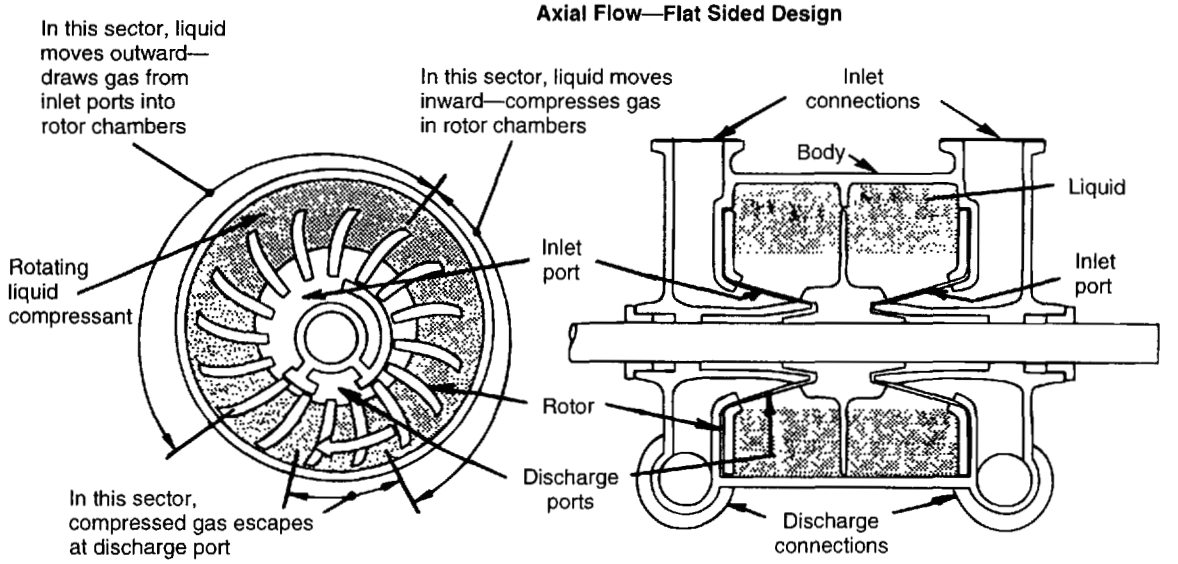
ACCESSORY EQUIPMENT (CONTINUED)	MANUFACTURER'S DATA (CONTINUED)
○ SURGE CAPACITORS:	Limit End Float to:
○ LIGHTNING ARRESTERS	Curves Req'd Based on Mtr. Saturation & Rated Volt:
○ C.T. FOR AMMETER	○ Speed vs. Torque @ 100%, 90% & 80% rated Voltage:
○ Description:	○ Speed vs. Current @ 100%, 90% & 80% rated Voltage:
MAIN CONDUIT BOX SIZED FOR:	
○ Main Motor Leads ○ Type:	WEIGHT (Lb.):
○ Insulated ○ Non-Insulated	Net Weight: Shipping Weight:
○ C.T.'s for Diff. Protection (mounted by):	Rotor Weight: Max. Erection Wt.:
○ Surge Capacitors (mounted by):	Max. Maint. Wt. (Identify):
○ Lightning Arresters (mounted by):	DIMENSIONS (Feet & Inches):
○ C.T. for Ammeter (mounted by):	L: W: H:
○ Space for Stress Cones:	
○ AIR FILTERS:	
☐ Mfr · ☐ Type:	

MANUFACTURER'S DATA	SHOP INSPECTION AND TESTS		
		Req'd.	Witness
Manufacturer:	Shop Inspection:	○	○
Frame No.: Full Load RPM (Ind.):	Testing per NEMA·	○	○
Efficiency: F.L. 3/4L 1/2L	Mfr. Std. Shop Tests:	○	○
Pwr Factor (Ind.): F.L. 3/4F 1/2L	Immersion Test:	○	○
Curr. (Rated Volt.): Full Load: Locked Rotor:	Special Tests (list below):	○	○
Locked Rotor Power Factor:		○	○
Locked Rotor w/Stand Time (cold start)·		○	○
Locked Rotor w/Stand Time (hot start):		○	○
Torques (Ft.-Lb.): Full Load:		○	○
Locked Rotor· Starting (Syn.):			
Pull-Up (Ind.). Pull-In (Syn.):	PAINTING:		
Breakdown (Ind.) Pull-Out (Syn.):	○ Manufacturer's Standard		
	○		
Open Circuit Time Constant (Sec.):	○		
Symmetrical Contribution to 3 Phase Terminal Fault			
at 1/2 Cycle. at 3 Cycles.	SHIPMENT		
Reactances: Sub-Transient (X"D)·	○ Domestic ○ Export ○ Export Boxing Req'd		
Transient (X'D): Synchronous (XD):	○ Outdoor Storage Over 3 Months		
A.C Stator Resistance: Ohms @ (°F)	○		
Rated kVA:	○		
kVA Inrush @ Full Volt. & Locked Rotor (Syn.) %			
kVA @ Full Voltage & 95% Speed: %	REMARKS:		
Max. Line Curr. in Stator on 1st Slip Cyc. & Pull-Out (Syn.):			
Acceleration Time (Mtr only & Rated Volt.) Sec.			
Accel Time (Mtr. & Load & 85% Rated Volt): Sec			
Rotor/Field Wk^2 & Mtr. Shaft (Lb -Ft^2)			
No. of Starts per Hour:			
Bearing: Type: Lubr..			
Lube Oil Required: (gpm) & (psig)			
Total Shaft End Float:			

APPENDIX B—LIQUID RING VACUUM PUMP SCHEMATIC



Axial Flow—Flat Sided Design



Radial Flow—Conical Design

The Liquid Ring Pumping Action

The rotor propels a band of ring liquid that rotates inside the cylindrical body The rotor axis is offset from the body axis. As centrifugal force forms the ring of liquid inside the body, it almost fills, then almost empties, each rotor chamber during a single revolution. This sets up the piston action.

Vacuum inlet ports and atmospheric discharge ports provide flow paths at the inner edges of the rotor chambers for the gas mixture being handled.

Rotor Imbalance

As can be seen in the above diagrams and the previous paragraphs, the liquid ring rotates at the same speed as the rotor but is offset from the axis of the rotor.

If, for example, the rotor has twenty chambers, twenty liquid pistons complete an outward inlet and an inward discharge stroke for each revolution of the rotor. The frequency of this imbalanced piston would be twenty times the rotational or equal to the vane passing frequency.

Because of the large mass and higher frequency of the liquid piston, the rotor imbalance becomes a minor factor, and the liquid piston imbalance becomes a major factor in the vibration characteristics of the entire system.

Figure B-1—Liquid Ring Vacuum Pump Schematic

APPENDIX C—SHAFT DEFLECTION SCHEMATIC

Notes:

1. As in any machine, the static weight "W" of the liquid ring pump shaft and rotor will deflect the shaft downward. This results in an upward deflection of the shaft extension.

2. Due to the operational characteristics of the liquid ring pump, a pressure differential exists between the inlet and discharge of the pump. This pressure difference "F" will deflect the shaft extension. This change in deflection at the extension "X" may be as much as 0.005 inch and will vary directly with differential pressure.

Figure C-1—Shaft Deflection Schematic

APPENDIX D—LIQUID RING VACUUM PUMP RING LIQUID FLOW SCHEMATICS

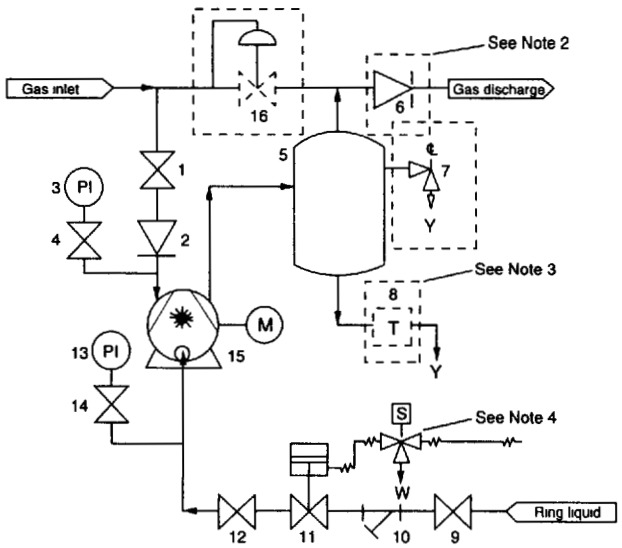


Figure A—LRVP Once Through System

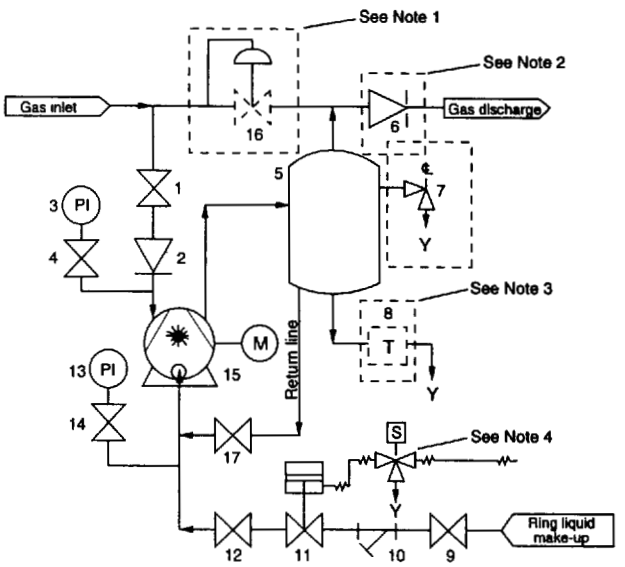


Figure B—LRVP Partial Recirculation System

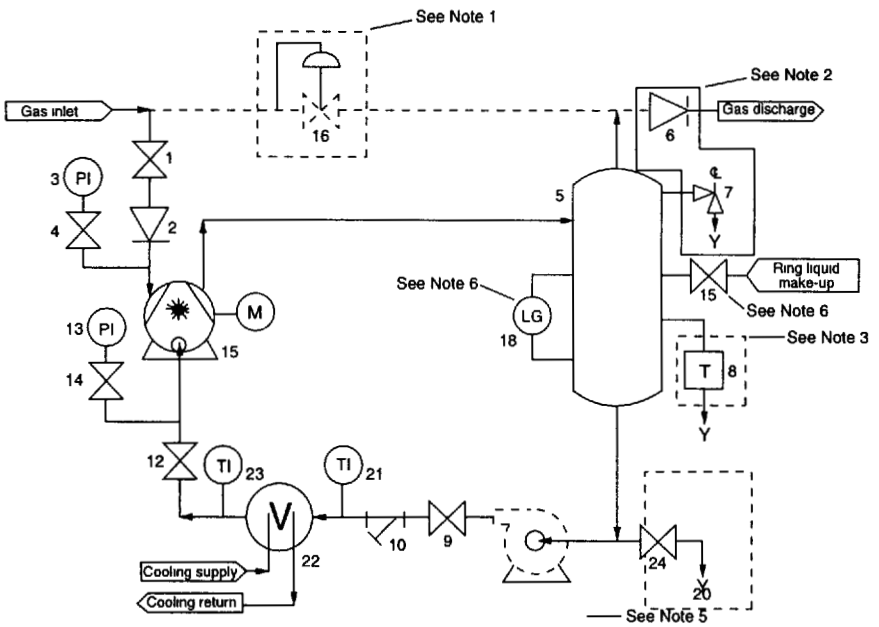


Figure C—LRVP Total Recirculation System

Figure D-1—Liquid Ring Vacuum Pump Ring Liquid Flow Schematics

Key to Parts

Figures A & B

1. Inlet isolating valve.
2. Inlet check valve.
3. Inlet pressure gauge.
4. Gauge isolation valve.
5. Gas/ring liquid separator.
6. Discharge check valve (see Note 2).
7. Pressure relief valve (see Note 2).
8. Ring liquid drain trap (see Note 3).
9. Inlet isolating valve.
10. Y Strainer.
11. Pilot operated automatic valve (see Note 4).
12. Flow regulating valve or orifice.
13. Ring liquid pressure gauge.
14. Gauge isolating valve.
15. Liquid ring pump and drive.
16. Inlet pressure control (see Note 1).
17. Partial ring liquid recirculation valve (Figure B only).

Figure C–Additions

18. Level gauge.
19. Make-up valve.
20. Optional ring liquid recirculation pump.
21. Temperature gauge.
22. Heat exchanger.
23. Temperature gauge.
24. Drain valve.

Notes

1. Optional inlet pressure control valve.

2. Optional pressurized discharge check valve and pressure relief valve. (Required on liquid ring compressors or vacuum pumps with positive discharge to a contained system.)

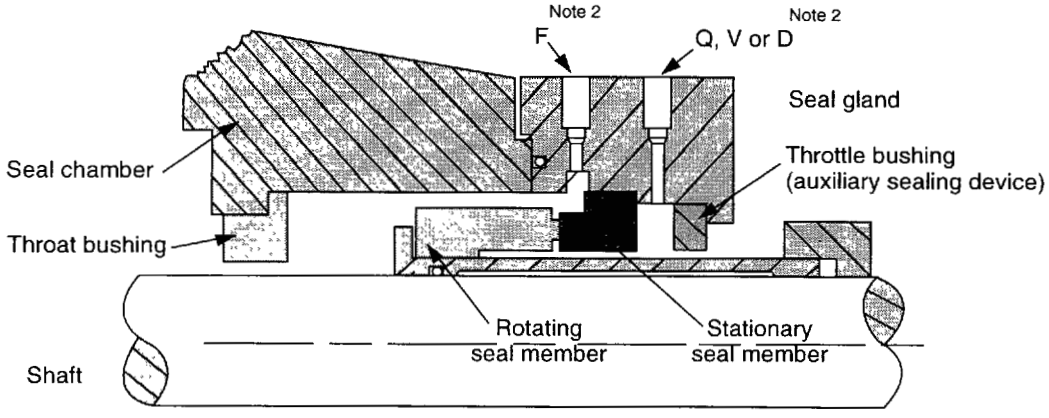
3. Optional pressurized discharge ring liquid drain system. (Required for compressors.)

4. Pilot operated isolating valve. Direct acting solenoid may be substituted at purchaser's discretion for small sizes.

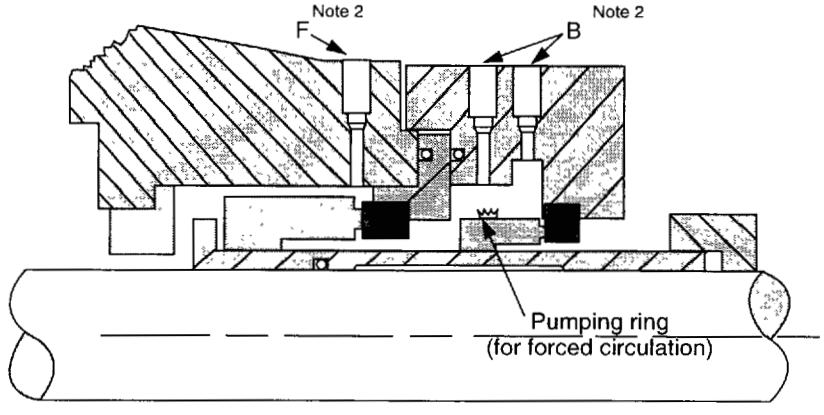
5. Recirculation pump optional based on purchaser's requirements or application details.

6. Optional level controls may be specified by purchaser.

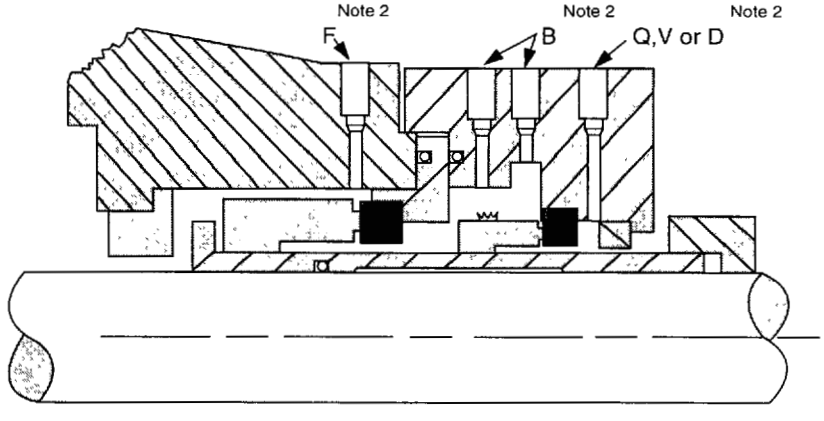
APPENDIX E—MECHANICAL SEAL AND PIPING ARRANGEMENT SCHEMATICS



SINGLE SEAL



UNPRESSURIZED DUAL SEAL



PRESSURIZED DUAL SEAL

Legend: F–Flush Q–Quench V–Vent D–Drain B–Barrier

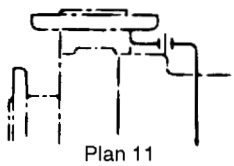
Figure E-1—Typical Mechanical Seal Arrangements

CLEAN PUMPAGE

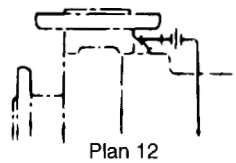
Plan 1
Integral (Internal) recirculation from pump discharge to seal

Plugged connections for possible future circulating fluid

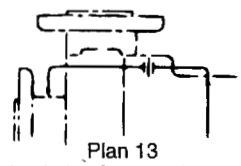
Plan 2
Dead-ended seal chamber with no circulation of flushed fluid; water cooled stuffing-box jacket and throat bushing required when specified



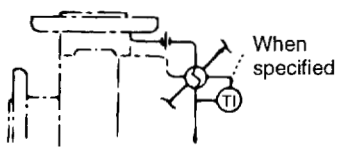
Plan 11
Recirculation from pump case through orifice to seal



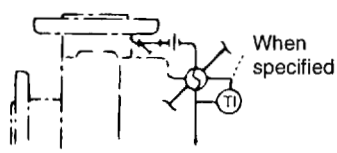
Plan 12
Recirculation from pump case through strainer and orifice to seal



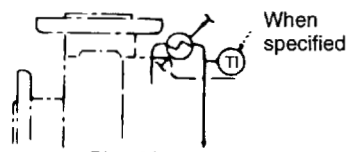
Plan 13
Recirculation from seal chamber through orifice and back to pump suction



Plan 21
Recirculation from pump case through orifice and heat exchanger to seal

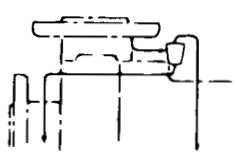


Plan 22
Recirculation from pump case through strainer, orifice, and heat exchanger to seal

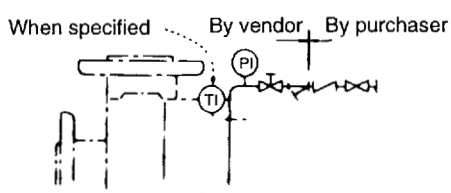


Plan 23
Recirculation from seal with pumping ring through heat exchanger and back to seal

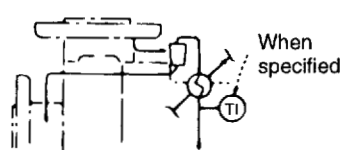
DIRTY OR SPECIAL PUMPAGE



Plan 31
Recirculation from pump case through cyclone separator delivering clean fluid to seal and fluid with solids back to pump suction



Plan 32
Injection to seal from external source of clean fluid (see Note 3)



Plan 41
Recirculation from pump case through cyclone separator delivering clean fluid through heat exchanger to seal and fluid with solids back to pump suction

LEGEND

Heat exchanger

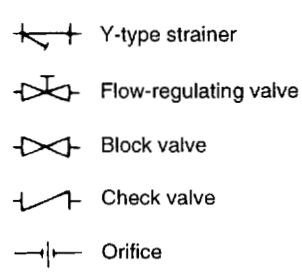
PI Pressure gauge with block valve

TI Dial thermometer

PS Pressure switch with block valve

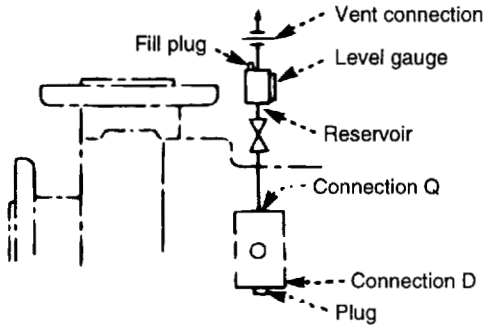
Cyclone separator

FI Flow indicator

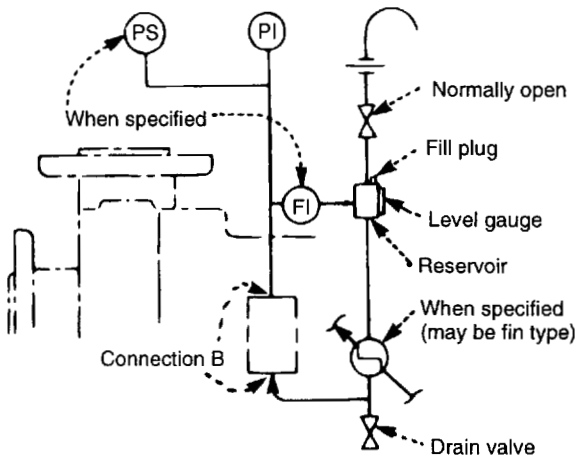


Notes:
1. These plans represent commonly used systems. Other variations and systems are available and should be specified in detail by the purchaser or mutually agreed upon by the purchaser and the vendor.
2 These plans are for use with Connection F on the single- and tandem-seal arrangements shown in Figure E-1.
3. For Plan 32, the purchaser will specify the fluid characteristics, and the vendor shall specify the volume, pressure, and temperature required.

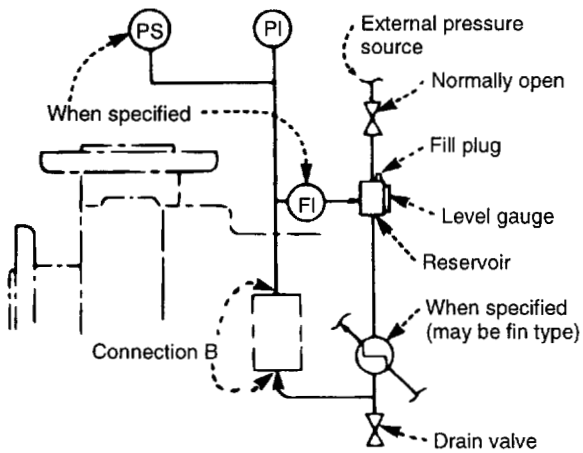
Figure E-2—Piping for Single-Seal Arrangements and Primary Seals of Tandem-Seal Arrangements



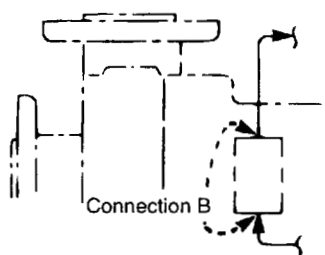
Plan 51
Dead-ended blanket (usually methanol, see Note 3); typically used with auxiliary sealing device (single- or double-seal arrangement in Figure E-1)



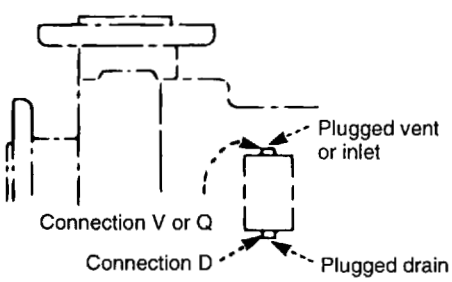
Plan 52
Nonpresssurized external fluid reservoir (see Note 3) with forced circulation; typically used with tandem-seal arrangement in Figure E-1



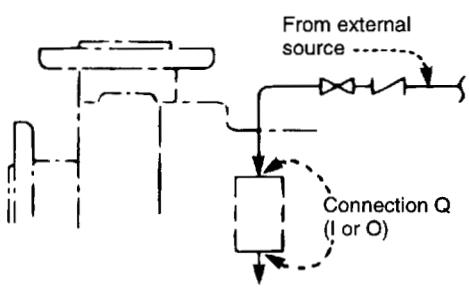
Plan 53
Presssurized external fluid reservoir (see Note 3) with forced circulation; typically used with tandem-seal arrangement in Figure E-1



Plan 54
Circulation of clean fluid from external system (see Note 3); typically used with double-seal arrangement in Figure E-1



Plan 61
Tapped connections for purchaser's use; Note 3 applies when purchaser is to supply fluid (steam, gas, water, etc.) to auxiliary sealing device (single- or double-seal arrangement in Figure E-1)



Plan 62
External fluid quench (steam, gas, water, etc.; see Note 3); typically used with throttle bushing or auxiliary sealing device (single- or double-seal arrangement in Figure E-1)

Notes:
1 These plans represent commonly used systems. Other variations and systems are available and should be specified in detail by the purchaser or mutually agreed upon by the purchaser and the vendor.
2. See Figure E-2 for explanation of symbols not specified here.
3. When supplemental seal fluid is provided, the purchaser will specify the fluid characteristics. The vendor shall specify the volume, pressure, and temperature required, where these are factors.

Figure E-3—Piping for Throttle Bushing, Auxiliary Seal Device, Tandem Seals, or Double Seals

APPENDIX F—MATERIAL LIST

Table F-1—Material List

Major Part Location	Material	Specification	Grade
Cast parts– casings and internals	Grey iron	ASTM A48 AS 1830 DIN 1691 SIS 0115 BS 1452	Class 20 min. Grade T150 min. GG10 min. MNC 705 min. Grade 150 min.
	Ductile iron	ASTM A536 ASTM A395 DIN 1693 SIS 1407 BS 2789	60-45-12 min. 60-40-18 min.
	Austenitic ductile iron	ASTM A439 BS 3468	
	Carbon steel	ASTM A216	WCA min.
	Stainless steel	ASTM A351, A743 or A744 DIN 17445 SIS 2343 or 2353 BS 1504	CF3, CF3M, CF8, CF8M, CA6NM, or CN7M 1.4581, 1.44406, 1.4410
	Nickle & nickle alloys	Hastelloy B Hastelloy C ASTM A494	Hastelloy B Hastelloy C-4 CW-2M, CQ-7M or N12
Fabricated parts- casings and internals	Steel	ASTM A36, A53, A203 or A516 DIN 17100 BS 3100	 A1
	Stainless steel	ASTM A240 or A276 DIN 17440 BS 970	304, 304L, 316, 316L or 316TL
	Nickle & nickle alloys	Hastelloy B Hastelloy C ASTM B333 ASTM B575	Hastelloy B-2 Hastelloy C-276 N10001 min. N10276
Shafts	Steel	ASTM A29 or A576 DIN 17440	1045
	Martensitic stainless steel	ASTM A276 DIN 17440	420 or 431 1.4021
	Austenitic stainless steel	ASTM A276 DIN 17440	303, 304, 316 or 329 1.4401
	Duplex stainless steel	ASTM A572 DIN 17440	65 1.0080
	Nickle & nickle alloys	Hastelloy B Hastelloy C ASTM B335 ASTM B574	Hastelloy B Hastelloy C-276 N10001 min. N10276
Shaft sleeves	Martensitic stainless steel	ASTM A276 DIN 17440	420 1.4021
	Austenitic stainless steel	ASTM A276 DIN 17440	304 or 316 1.4401
	Nickle & nickle alloys	Hastelloy B Hastelloy C ASTM B335 ASTM B574	Hastelloy B Hastelloy C-276 N10001 min. N10276

Note: Temperature limitation –40°F to 250°F

APPENDIX G—LIQUID RING VACUUM PUMPS AND COMPRESSORS VENDOR DRAWING AND DATA REQUIREMENTS

LIQUID RING VACUUM PUMPS AND COMPRESSORS VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. _____ ITEM NO. _____
PURCHASE ORDER NO. _____ DATE _____
REQUISITION NO. _____ DATE _____
INQUIRY NO. _____ DATE _____
PAGE 1 OF 2 BY _____

FOR _____ REVISION _____
SITE _____ UNIT _____
SERVICE _____ NO. REQUIRED _____

Proposal[a] Bidder shall furnish _____ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish _____ copies and _____ transparencies of drawings and data indicated.

Final[b] Vendor shall furnish _____ copies and _____ transparencies of drawings and data indicated.
Vendor shall furnish _____ operating and maintenance manuals.

Final—Received from vendor
Due from vendor[c]
Review—Returned to vendor
Review—Received from vendor
Review—Due from vendor[c]

			LIQUID RING PUMP OR COMPRESSOR					
			1. Certified dimensional outline drawing and list of connections.					
			2. Cross-sectional drawings and bill of materials.					
			3. Shaft seal drawing and bill of materials.					
			4. Coupling assembly drawing and bill of materials.					
			5. Ring liquid schematic and bill of materials.					
			6. Cooling water schematic and bill of materials.					
			7. Ring liquid system arrangement drawing and list of connections.					
			8. Ring liquid component drawings and data.					
			9. Electrical and instrumentation schematics and bill of materials.					
			10. Electrical and instrumentation arrangement drawing and list of connections.					
			11. Performance curves.					
			12. Vibration analysis data.					
			13. Lateral critical speed analysis.					
			14. Torsional critical speed analysis.					
			15. Certified hydrostatic test data.					
			16. Progress reports.					
			17. Weld procedures.					
			18. Performance test data.					
			19. Certified rotor balance data.					
			20. As-built data sheets.					
			21. As-built clearances.					
			22. Installation, operation, and maintenance manuals.					
			23. Spare parts recommendations.					
			24. List of drawings.					
			25. List of special tools furnished for maintenance.					
			26. Material safety data sheets.					
			27. Relief valve calculations.					

[a]Proposal drawings and data do not have to be certified or as-built.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

JOB NO. _____ ITEM NO._____
PAGE 2 OF 2 BY _____
DATE _____ REV. NO. _____

LIQUID RING VACUUM PUMPS AND COMPRESSORS VENDOR DRAWING AND DATA REQUIREMENTS

Proposal[a] Bidder shall furnish _____ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish _____ copies and _____ transparencies of drawings and data indicated.

Final[b] Vendor shall furnish _____ copies and _____ transparencies of drawings and data indicated.
Vendor shall furnish _____ operating and maintenance manuals.

Final—Received from vendor _____
Due from vendor[c] _____
Review—Returned to vendor _____
Review—Received from vendor _____
Review—Due from vendor[c] _____

			MOTOR						
			28. Certified dimensional outline drawing.						
			29. Cross-sectional drawing and bill of materials.						
			30. As-built data sheets.						
			31. Performance data.						
			32. Certified drawings of auxiliary systems.						
			33. Installation, operation, and maintenance manuals						
			34. Spare parts recommendations.						
			GEAR						
			35. Certified dimensional outline drawings and list of connections						
			36. Cross-sectional drawing and bill of materials.						
			37 As-built data sheets.						
			38. Mechanical running test log.						
			39 Gear manufacturer's standard test logs						
			40 Optional test data and reports.						
			41 Installation, operation, and maintenance manuals.						
			42. Spare parts recommendations.						

[a]Proposal drawings and data do not have to be certified or as-built.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of the form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

Notes:
1. Send all drawings and data to _____
_____
2. All drawings and data must show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation must be forwarded with the shipment.
3. See expanded description of specified in items below.

Nomenclature:
_____ S—number of weeks prior to 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)

APPENDIX H—SYSTEM CONSIDERATIONS, OPERATING VARIABLES, AND TEST PERFORMANCE CONVERSION

H.1 System Consideration—Factors Affecting Performance and Selection of Liquid Ring Vacuum Pump and Compressor Systems

Liquid ring vacuum pump and compressor performance in the user's process is significantly influenced by process variables. Process variables which must be considered during process development, design, and specification may include:

H.1.1 VARIABLES FOR GAS INLET TO PUMPING (OR COMPRESSING) EQUIPMENT

H.1.1.1 Temperature, pressure, mass flows, and molecular weights.

H.1.1.2 Saturation conditions and heats of vaporization and condensation.

H.1.1.3 Solubility of gases in the ring liquid fluid.

H.1.1.4 Presence of liquid or solid carryover, and particle size if applicable.

H.1.1.5 Variations with time in process gas specification (that is, batch processes).

H.1.1.6 Pump-up or pump-down time limitations.

H.1.1.7 Reactivity of the gas, or effects of the gas on the ring liquid.

H.1.2 VARIABLES FOR GAS DISCHARGED TO PROCESS OR VENT SYSTEM

H.1.2.1 Maximum (allowable) temperatures.

H.1.2.2 Pressures, including maximum allowable.

H.1.2.3 Gas mass flows required or desired downstream.

H.1.2.4 Permitted (or allowable) liquid carryover from the system.

H.1.2.5 Permitted (or allowable) vapor carryover from the system.

H.1.3 VARIABLES FOR RING LIQUID SYSTEM

H.1.3.1 Temperatures and pressures at the inlet to the system.

H.1.3.2 Temperatures and pressures required (or desired) at the discharge from the system.

H.1.3.3 Vapor pressure under equilibrium conditions at the pump or compressor suction and discharge within the operating range.

H.1.3.4 Specific gravity in the operating range.

H.1.3.5 Viscosity in the operating range.

H.1.3.6 Reactivity with the gas stream, if applicable.

H.1.3.7 Miscibility/solubility with inlet liquids or condensed vapors.

H.1.3.8 Fouling potential.

H.1.3.9 Specific heat and thermal conductivity within the operating ranges.

H.2 Operating Variables—Checklist

H.2.1 Inlet mixture may be cooled in pump increasing net capacity.

H.2.2 Inlet mixture may or may not be saturated with condensable vapors.

H.2.3 Inlet condensables may be miscible or immiscible wtih other or with service liquid.

H.2.4 Inlet condensables may be partially condensed in pump increasing net capacity.

H.2.5 Cooler service liquid temperature may increase net capacity and lower effective vapor pressure of service liquid.

H.2.6 Lower service liquid effective vapor pressure may increase net capacity.

H.2.7 Condensing vapors may increase service liquid temperature rise and increase heat load to optional heat exchanger.

H.2.8 Service liquid specific heat lower than water may increase temperature rise.

H.2.9 Service liquid specific gravity lower than water may affect performance.

H.2.10 Service liquid specific viscosity lower than water may decrease BHP and, in turn, reduce service liquid temperature rise.

H.2.11 Solubility of inlet gas in service liquid may reduce net capacity.

H.2.12 Inlet vapors may condense and contaminate the service liquid modifying its characteristics. Miscible condensables may accumulate in service liquid and become a dominant factor in determining net effective vapor pressure. Immiscible condensables with lower specific gravity than service liquid may collect at gas/liquid interface and

become dominant factors in determining net effective vapor pressure.

H.2.13 Net performance is generally determined by vapor pressure at effective service liquid temperature. For two stage pumps, the latter is the interstage temperature.

H.2.14 Higher service liquid rate may reduce temperature rise and increase net capacity at rated conditions.

H.2.15 Service liquid type may determine effective service liquid temperature and performance.

Once-through generally provides lowest service liquid temperature with higher effective service liquid temperature.

Full recirculation permits use of separate coolant medium–generally with higher effective service liquid temperature. A minimal service liquid purge flow should be used to control service liquid contamination.

H.2.16 Back pressures other than standard will affect performance.

H.3 Conversion of Standard Test Performance to Specified Operating Conditions

H.3.1 Since operating conditions with respect to inlet gases, condensable vapors, service liquid, and other field conditions are often different from those of the Standard Test, a conversion must be carried out. Conversions of this kind shall be based upon the manufacturer's standard method and shall be agreed upon before-hand by the parties involved.

H.3.2 A check list of operating variables will provide the user with a better understanding of conversions to be made.

H.3.3 It should be noted that a rigorous mathematical solution or conversion is generally not practicle. The equipment selection procedure is usually a reiteration of a series of approximations. The latter are based upon a combination of user and manufacturer field experience, vendor laboratory tests, and similarity.

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