Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services

API STANDARD 618
FOURTH EDITION, JUNE 1995

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services

Manufacturing, Distribution and Marketing

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FOREWORD

This standard is based on the accumulated knowledge and experience of manufacturers and users of reciprocating compressors. The objective of this publication is to provide a purchase specification to facilitate the manufacture and procurement of reciprocating compressors for petroleum, chemical, and gas industry services.

The primary purpose of this standard is to establish minimum electromechanical requirements. This limitation in scope is one of charter as opposed to interest and concern. Energy conservation is of concern and has become increasingly important in all aspects of equipment design, application, and operation. Thus, innovative energy-conserving approaches should be aggressively pursued by the manufacturer and the user during these steps. Alternative approaches that may result in improved energy utilization should be thoroughly investigated and brought forth. This is especially true of new equipment proposals, since the evaluation of purchase options will be based increasingly on total life costs as opposed to acquisition cost alone. Equipment manufacturers, in particular, are encouraged to suggest alternatives to those specified when such approaches achieve improved energy effectiveness and reduced total life costs without sacrifice of safety or reliability.

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 this standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard, rather than by rewriting or incorporating sections thereof into another complete standard.

API standards are published as an aid to procurement of standardized equipment and materials. These standards are not intended to inhibit purchasers or producers from purchasing or producing products made to specifications other than those of API.

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IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of extreme usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products, published at 54 *Federal Register* 29460 (July 12, 1989).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

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Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services

SECTION 1—GENERAL

1.1 Scope

1.1.1 This standard covers the minimum requirements for reciprocating compressors and their drivers used in petroleum, chemical, and gas industry services for handling process air or gas with either lubricated or nonlubricated cylinders. Compressors covered by this standard are of moderate-to-low speed and in critical services. Also covered are related lubricating systems, controls, instrumentation, intercoolers, aftercoolers, pulsation suppression devices, and other auxiliary equipment. Compressors not covered are (a) integral gas-engine-driven compressors with single-acting trunk-type (automotive-type) pistons that also serve as crossheads and (b) either plant or instrument-air compressors that discharge at a gauge pressure of 9 bar (125 pounds per square inch) or less. Also not covered are gas engine and steam engine drivers.

Note: Requirements for packaged high-speed reciprocating compressors for oil and gas production services are covered in API Specification 11P.

1.1.2 Requirements for packaged reciprocating plant and instrument-air compressors are covered in API Standard 680.

Note: A bullet (●) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets (see Appendix A); otherwise it 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

Some of the terms used in this standard are defined in 1.4.1 through 1.4.37.

● **1.4.1** *Acoustical simulation* is the process whereby the one-dimensional acoustical characteristics of fluids and the reciprocating compressor dynamic flow influence on these characteristics are modeled. The model is mathematically based on the governing differential equations (those concerning motion, continuity, and the like). The simulation should allow for determination of pressure and /or flow modulations resulting from any generalized compressor excitation at any point in the piping model. (Refer also to 1.4.2, 1.4.4, 1.4.7, 1.4.19, 1.4.24, and 1.4.33.)

1.4.2 An *active analysis* is a portion of the acoustical simulation that simulates the pressure pulsation amplitudes due to imposed compressor(s) operation of the anticipated loading, speed range, and stated conditions. (Refer to 1.4.1.)

1.4.3 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.

1.4.4 *Analog simulation* is the use of electrical components (inductances, capacitors, resistances, and current supply devices) to achieve the acoustical simulation. (Refer to 1.4.1.)

1.4.5 *Combined rod loading* is the algebraic sum of gas load and inertia force. Gas load is the force resulting from differential gas pressure acting on the piston differential area. Inertia force is that force resulting from the acceleration of reciprocating mass. The inertia force with respect to the crosshead pin is the summation of all reciprocating masses (piston and rod assembly, and crosshead assembly including pin) times their acceleration.

1.4.6 The use of the word *design* in any term (such as *design power*, *design pressure*, *design temperature*, or *design speed*) should be avoided in the purchaser's specifications. This terminology should be used only by the equipment designer and the manufacturer.

1.4.7 *Digital simulation* is the use of various mathematical techniques on digital computers to achieve the acoustical simulation. (Refer to 1.4.1.)

1.4.8 A *gauge board* is an unenclosed bracket or plate used to support and display gauges, switches, and other instruments.

1.4.9 *Inlet volume* is the flow rate determined at the conditions of pressure, temperature, compressibility, and gas composition—including moisture—at the compressor inlet flange. To determine inlet volume flow, allowance must be made for pressure drop across pulsation suppression devices and for interstage liquid knockout.

1.4.10 *Local* refers to a device mounted on or near the equipment or console.

1.4.11 *Manufacturer's rated capacity* is the capacity used to size the compressor. When no negative tolerance applies, the manufacturer's rated capacity is calculated by dividing the required capacity by 0.97. This result accommodates the normal manufacturing tolerance so that the lower limit of the tolerance will never be less than the required capacity. Refer to Appendix B.

1.4.12 *Maximum allowable continuous combined rod loading* is the highest force that a manufacturer will permit for continuous operation on all running gear (piston, piston rod, crosshead assembly, connecting rod, crankshaft, and bearings).

1.4.13 *Maximum allowable continuous gas loading* is the highest force that a manufacturer will permit for continuous operation on the static components of the compressor (such as the frame, the distance piece, the cylinder, and the bolting).

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

1.4.15 *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.

1.4.16 *Maximum allowable working pressure (MAWP)* 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.

1.4.17 *Minimum allowable speed* (in revolutions per minute) is the lowest speed at which the manufacturer's design will permit continuous operation.

1.4.18 *Minimum allowable suction pressure* for each stage is the lowest pressure (measured at the inlet flange of the cylinder) below which the combined rod loading, or gas loading, or discharge temperature, or crankshaft torque loading (whichever is governing) will exceed the maximum allowable during operation at the set-point pressure of the discharge relief valve and at other specified gas conditions for the stage.

1.4.19 The *mode shape* of an acoustical pulsation resonance defines the pulsation amplitudes and phase angles relationship at various points in the piping system. Knowledge of the mode shape allows the analyst to understand the pulsation patterns in the piping system. (Refer to 1.4.1.)

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

1.4.21 *Normally open* and *normally closed* refer both to on-the-shelf positions and to de-energized positions of devices such as automatically controlled electrical switches and valves. The normal operating position of such a device is not necessarily the same as the device's on-the-shelf position.

1.4.22 The *owner* is the final recipient of the equipment and may delegate another agent as the purchaser of the equipment.

1.4.23 A *panel* is an enclosure used to mount, display, and protect gauges, switches, and other instruments.

1.4.24 A *passive analysis* is a portion of the acoustic simulation that imposes on the system a constant flow amplitude modulation over an arbitrary frequency range, normally at the cylinder valve locations. The resulting transfer function defines the acoustical natural frequencies and the mode shapes over the frequency range of interest. (Refer to 1.4.1.)

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

1.4.26 *Rated discharge temperature* is the highest predicted operating temperature resulting from any specified operating condition.

● **1.4.27** *Rated power* of a compressor is the maximum power that the compressor plus any shaft-driven appurtenances require for any of the specified operating conditions. The rated power includes the effect of equipment such as pulsation suppression devices, process piping, intercoolers, aftercoolers, and separators. The effects of equipment outside the vendor's supply shall be provided by the purchaser. Driver losses are stated separately.

1.4.28 *Rated speed* (in revolutions per minute) is the highest speed required to meet any of the specified operating conditions.

1.4.29 *Remote* refers to a device located away from the equipment or console, typically in a control house.

1.4.30 *Required capacity* is the rated process capacity specified by the purchaser to meet process conditions with no negative tolerance permitted. Refer to Appendix B for an explanation of the term *no negative tolerance*.

1.4.31 *Rod reversal* is a change in direction of force in the piston-rod loading (from tension to compression or vice versa) that results in a load reversal at the crosshead pin during each revolution.

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

1.4.33 The *spectral frequency distribution* is the description of the pressure pulsation harmonic amplitudes versus frequency at a selected test point location for an active or passive acoustical analysis. (Refer to 1.4.2 and 1.4.24.)

1.4.34 *Standard flow* is the flow rate expressed in volume flow units. ISO standard flow rate is expressed in 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) and a temperature of 0°C (32°F). U.S. 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.

1.4.35 *Trip speed* (in revolutions per minute) is the speed at which the independent emergency overspeed device operates to shutdown a variable-speed prime mover (see Table 1).

1.4.36 *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.

1.4.37 *Vendor* is the agency that manufactures, sells, and provides service support for the equipment.

1.5 Referenced Publications

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

AFBMA[1]

Std 11 *Load Ratings and Fatigue Life for Roller Bearings*

API

Manual of Petroleum Measurement Standards, Chapter 15, "Guidelines for Use of the International System of Units (SI) in the Petroleum and Allied Industries"

Spec 11P *Packaged High Speed Separable Engine-Driven Reciprocating Gas Compressors*

RP 500 *Classification of Locations for Electrical Installations at Petroleum Facilities*

RP 520 *Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries,* Part I, "Sizing and Selection"; and Part II, "Installation"

Std 526 *Flanged Steel Safety-Relief Valves*

Std 541 *Form-Wound Squirrel-Cage Induction Motors—250 Horsepower and Larger*

Std 546 *Form-Wound Brushless Synchronous Motors—500 Horsepower and Larger*

RP 550 *Manual on Installation of Refinery Instruments and Control Systems,* Part I, "Process Instrumentation and Control" (out of print)

Std 594 *Wafer and Wafer-Lug Check Valves*

Std 600 *Steel Gate Valves—Flanged and Butt-Welding Ends*

Std 602 *Compact Steel Gate Valves*

Std 606 *Compact Carbon Steel Gate Valves—Extended Body*

Std 611 *General-Purpose Steam Turbines for Refinery Service*

Std 612 *Special-Purpose Steam Turbines for Refinery Services*

Std 613 *Special-Purpose Gear Units for Refinery Service*

Std 614 *Lubrication, Shaft-Sealing, and Control-Oil Systems for Special-Purpose Applications*

Std 615 *Sound Control of Mechanical Equipment for Refinery Services*

Std 616 *Gas Turbines for Refinery Services*

Std 660 *Shell-and-Tube Heat Exchangers for General Refinery Services*

Std 661 *Air-Cooled Heat Exchangers for General Refinery Service*

Std 670 *Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems*

Std 671 *Special-Purpose Couplings for Refinery Service*

Std 677 *General-Purpose Gear Units for Refinery Service*

Std 680 *Packaged Reciprocating Plant and Instrument Air Compressors for General Refinery Services (out of print)*

ASME[2]

Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination"; Section VIII, "Pressure

Table 1—Driver Trip Speeds

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

[a]NEMA Classes A, B, C, and D are governor classes as specified in NEMA SM 23.

[1]American Bearing Manufacturing Association, 1200 19th Street, N.W., Suite 300, Washington, D.C. 20036.

[2]American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

Vessels"; and Section IX, "Welding and Brazing Qualifications"

B1.1 *Unified Inch Screw Threads (UN and UNR Thread Form)*
B1.20.1 *Pipe Threads, General Purpose (Inch)*
B16.1 *Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800*
B16.5 *Pipe Flanges and Flanged Fittings*
B16.11 *Forged Fittings, Socket-Welding and Threaded*
B16.42 *Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300*
B31.3 *Chemical Plant and Petroleum Refinery Piping*
Y14.2M *Line Conventions and Lettering*

ASTM[3]

A 105 *Specification for Forgings, Carbon Steel, for Piping Components*
A 106 *Specification for Seamless Carbon Steel Pipe for High-Temperature Service*
A 181 *Specification for Forgings, Carbon Steel, for General Purpose Piping*
A 182 *Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*
A 193 *Specification 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 216 *Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service*
A 234 *Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*
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 307 *Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile*
A 312 *Specification for Seamless and Welded Austenitic Stainless Steel Pipe*
A 320 *Specification for Alloy-Steel Bolting Materials for Low-Temperature Service*
A 388 *Practice for Ultrasonic Examination of Heavy Steel Forgings*
A 395 *Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*
A 403 *Specification for Wrought Austenitic Stainless Steel Piping Fittings*
A 503 *Specification for Ultrasonic Examination of Large Forged Crankshafts*
A 515 *Specification for Pressure Vessel Plates, Carbon Steel, 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*
A 668 *Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use*
E 94 *Guide 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[4]

D1.1 *Structural Welding Code—Steel*

EPA[5]

40 *Code of Federal Regulations* Sections 61.140–156
54 *Federal Register* 29460

NACE[6]

MR0175 *Sulfide Stress Cracking Resistant-Metallic Materials for Oilfield Equipment*

NEMA[7]

MG 1 *Motors and Generators*
SM 23 *Steam Turbines for Mechanical Drive Service*

NFPA[8]

70 *National Electrical Code,* Articles 496, 500, 501, and 502

OSHA[9]

29 *Code of Federal Regulations* Section 1910.1001

[3]American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

[4]American Welding Society, 550 N.W. LeJeune Road, P. O. Box 351040, Miami, FL 33135.

[5]Environmental Protection Agency. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

[6]National Association of Corrosion Engineers, P. O. Box 218340, Houston, TX 77218.

[7]National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, D.C. 20037.

[8]National Fire Protection Association, 1 Batterymarch Park, P. O. Box 9101, Quincy, MA 02269-9101.

[9]Occupational Safety and Health Administration, U.S. Department of Labor. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

SSPC[10]

SP 6 *Commercial Blast Cleaning*

TEMA[11]

Standards of the Tubular Exchanger Manufacturers Association

1.5.2 This standard makes reference to American standards. The corresponding international publications as listed in Appendix Q may be acceptable as alternatives with the purchaser's approval. Other international or national standards may be used as mutually agreed between the purchaser and vendor provided it can be shown that these other standards meet or exceed the American standards referenced.

[10]Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213-2683.
[11]Tubular Exchanger Manufacturers Association, 25 North Broadway, Tarrytown, NY 10591.

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

1.5.4 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.

1.6 Unit Conversion

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

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 an expected uninterrupted operation of at least 3 years. It is recognized that this is a system design criterion.

● **2.1.2** 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.

2.1.3 Unless otherwise specified, cooling water systems shall be designed for the following conditions on the coolant side:

For Heat Exchangers		
Velocity in exchanger tubes[a]	1.5–2.5 m/s	5–8 ft/s
Maximum allowable working gauge pressure	≥ 7 bar	≥ 100 psi
Test pressure	1.5 x MAWP	1.5 x MAWP
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	30F°
Minimum temperature rise[a]	10K	20F°
Fouling factor on water side	0.35 K•m²/kW	0.002 hr-ft²°F/Btu
Shell corrosion allowance for carbon steel	3 mm	0.125 in
For Cylinder Jackets and Packing Cases		
Maximum allowable working gauge pressure	≥ 5 bar	≥ 75 psi
Test pressure	1.5 x MAWP	1.5 x MAWP

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

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

2.1.4 To avoid excitation of torsional, acoustical, and/or mechanical resonances, reciprocating compressors normally should be specified for constant-speed operation. When variable-speed drivers are used, all equipment shall be designed to run safely to the trip speed. For variable-speed drives, a listing of unsafe or undesirable speeds shall be furnished to the purchaser by the vendor. See 2.5 and 3.6.2.

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

2.1.6 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.

● **2.1.7** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, 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.

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

2.1.9 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as cylinders and compressor frames shall be designed (shouldered or cylindrically doweled) and manufactured to ensure accurate alignment on reassembly.

2.1.10 The compressor vendor shall assume unit responsibility for the engineering coordination of all equipment and for the performance of the entire compressor train consisting of compressor, driver, power transmission equipment, and all auxiliary equipment and systems included in the scope of the order and supplied by the compressor vendor.

The compressor vendor shall resolve all engineering questions or problems related to the equipment design, including coordination of changes as required.

● **2.1.11** After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility. Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) may adversely affect site performance. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings in accordance with the agreed schedule. The vendor's review of foundation drawings will be limited to anchor bolt layout and the vendor's input data used for foundation design. When specified, the purchaser and the manufacturer shall agree on the details of an initial installation check by the vendor's representative, and an operating temperature alignment check at a later date. These checks shall include but not be limited to initial alignment check, grouting, crankshaft web deflection, piston-rod runout, driver alignment, motor air gap, outboard bearing insulation and megger test, bearing clearance checks, and piston end clearance.

● **2.1.12** The purchaser will specify the equipment's normal operating point. Unless otherwise specified, the capacity at the normal operating point shall have no negative tolerance. (Refer to 1.4.11, 1.4.20, and 1.4.30.)

Note: See Appendix B for a discussion of capacity and the term *no negative tolerance*.

2.1.13 The power required by the compressor at the normal operating point shall not exceed the stated power by more than 3 percent.

● **2.1.14** 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 and unusual humidity, dust, or corrosive conditions). The unit and its auxiliaries shall be suitable for operation under these specified conditions.

2.1.15 The vendor shall use the specified values of weight flow, the specified gas analysis, and the gas conditions to calculate molecular weight, ratio of specific heats (C_p/C_v), compressibility factors (z), and inlet volume flow. The compressor vendor shall indicate his values on the data sheets with the proposal and use them to calculate performance data.

● **2.1.16** If any of the compressor cylinders are to be operated partially or fully unloaded for extended periods of time, the purchaser and the vendor shall jointly determine the method to be used (for example, periodic momentary loading) to purge accumulation of lube oil in the compressor cylinders in order to prevent heat and liquid damage.

2.1.17 Compressors shall be capable of developing the maximum differential pressure specified by the purchaser. The compressor vendor shall confirm that the unit is capable of continuous operation at any full-load, part-load (refer to 2.4.2), or fully unloaded conditions (refer to 2.1.16) and that the unit is capable of start-up in accordance with 3.1.1.3.

2.1.18 Compressors driven by induction motors shall be rated at the actual motor speed for the rated load condition, not at synchronous speed.

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

● 2.2 Allowable Speeds

Compressors shall be conservatively rated at a speed not in excess of that known by the manufacturer to result in low maintenance and trouble-free operation under the specified service conditions. The maximum acceptable average piston speed (in meters per second or feet per minute) and the maximum acceptable speed (in revolutions per minute) may be specified by the purchaser where experience indicates that specified limits should not be exceeded for a given service.

Note: Generally, the rotative and piston speeds of compressors in nonlubricated services should be less than those in equivalent lubricated services.

2.3 Allowable Discharge Temperature

2.3.1 Unless otherwise specified and agreed, the maximum predicted discharge temperature shall not exceed 150°C (300°F). This limit applies to all specified operating and load conditions. The vendor shall provide the purchaser with both the predicted and adiabatic discharge temperature rise.

Special consideration shall be given to services (such as those with high-pressure hydrogen or applications requiring nonlubricated cylinders) where temperature limitations should be lower. Predicted discharge temperatures shall not exceed 135°C (275°F) for hydrogen-rich services (those with molecular weight of 12 or less).

Note: The actual discharge temperature will vary from the adiabatic depending on such factors as the power input to a cylinder, the ratio of compression, the size of the cylinder, the surface area of the cooling passages, and the velocity of the coolant. Nonlube hydrogen service will generally have higher discharge temperatures than lube hydrogen service due to slippage and the unusual characteristic of hydrogen which may heat when it expands. With low power and small cylinders, the actual temperature can be below adiabatic, which may allow a lesser number of stages if the application is borderline. Conversely, large cylinders may result in a temperature rise higher than adiabatic and require additional stages.

Generally, compression ratios are higher in the first and second stages for full load. When the unit is unloaded by clearance pockets in lower stages, the higher stages have the higher compression ratios. The discharge temperature should be reviewed at all loading points.

● **2.3.2** A high-discharge-temperature alarm and shutdown is required for each compressor cylinder. When specified, 100-percent unloading shall be furnished as part of this system. The supplier of these devices, the set-points, and the operation mode shall be agreed on by the purchaser and the compressor vendor.

Note: The recommended discharge-temperature alarm and trip set-points are 20K (40F°) and 30K (50F°) respectively over the maximum predicted discharge temperature; but in no case should temperature trip set-points exceed 180°C (350°F). To prevent autoignition, lower temperature set-point limits should be considered for air—because of its oxygen content—if the discharge gauge pressure exceeds 20 bar (300 pounds per square inch). Use of synthetic oils, although not intended as a means to increase the allowable discharge temperature, is recommended for additional safety (see 2.13.1.9).

CAUTION: Oxygen-bearing gases other than air require special consideration.

2.4 Rod and Gas Loadings

2.4.1 The combined rod loading shall not exceed the manufacturer's maximum allowable continuous combined rod loading for the compressor running gear at any specified operating load step. These combined rod loads shall be calculated on the basis of the set-point pressure of the discharge relief valve of each stage and of the lowest specified suction pressure corresponding to each load step.

2.4.2 The gas loading shall not exceed the manufacturer's maximum allowable continuous gas loading for the compressor static frame components (cylinders, heads, distance pieces, crosshead guides, crankcase, and bolting) at any specified operating load step. These gas loads shall be calculated on the basis of the set-point pressure of the discharge relief valve of each stage and of the lowest specified suction pressure corresponding to each load step.

2.4.3 The combined rod loads and the gas loads shall be calculated for each 10-degree interval of one crankshaft revolution for each specified load step based on internal cylinder pressures using valve and gas passage losses and gas compressibility factors corresponding to the internal cylinder pressure and temperature conditions at each crank angle increment. The internal pressure during the suction stroke is the normal suction pressure (at cylinder flange) minus the valve and gas passage losses. The internal pressure during the discharge stroke is the normal discharge pressure (at cylinder flange) plus the valve and gas passage losses.

2.4.4 For all specified operating load steps and the fully unloaded condition, the component of combined rod loading parallel to the piston rod shall fully reverse between the crosshead pin and bushing during each complete turn of the crankshaft. Unless otherwise specified, the duration of this reversal shall not be less than 15 degrees of crank angle, and the magnitude of the peak combined reversed load shall be at least 3 percent of the actual combined load in the opposite direction. (This reversal is required to maintain proper lubrication between the crosshead pin and bushing.)

2.4.5 The compressor shall be capable of handling momentary excursions of operation up to 10-percent above the maximum allowable continuous combined rod-load and maximum allowable continuous gas-load ratings. These excursions shall be limited to a duration of less than 30 seconds and a frequency of no more than twice in a given 24-hour period.

Note: The above analysis of rod load and gas load is significantly different from that of the previous methods used to calculate rod loads, which used only cylinder differential pressure and piston areas and did not take into account valve losses and other factors. Previous methods, therefore, required the application of a factor to the manufacturer's published rod-load ratings to account for these formerly unknown losses. Using the above method, the maximum loadings will occur at some crank angle before the end of the stroke. This maximum load-angle will vary by application and will depend on the ratio of compression, the gas characteristics, and the valve and passage losses. The magnitudes of maximum rod loading and maximum gas loading may be of different values and may occur at different crank angles. Maximum allowable frame ratings (gas loading) may not always be the same value as the maximum allowable rod-load ratings.

2.5 Critical Speeds

2.5.1 The compressor vendor shall provide the necessary lateral and torsional studies required to eliminate any lateral or torsional vibrations that may hinder the operation of the complete unit within the specified operating speed range in any specified loading step. The vendor shall inform the purchaser of all critical speeds from zero to trip speed or synchronous speed that occur during acceleration or deceleration (see 5.2.3, Item s).

2.5.2 Except for belt driven units, the vendor shall provide a torsional analysis of the complete drive train. Torsional natural frequencies of the driver-compressor system (including couplings and any gear unit) shall be avoided within 10 percent of any operating shaft speed and within 5 percent of any other multiple of operating shaft speed in the rotating system up to and including the tenth multiple. For motor-driven compressors, torsional natural frequencies shall be separated from the first and second multiples of the electrical power frequency by the same separation margins.

2.5.3 For drive trains that include a turbine and gear, the requirements of API Standards 611, 612, 613, 616, and 677, as applicable, shall govern in calculation and evaluation of critical speeds. For units requiring the use of a low-speed quill shaft and coupling, a separate lateral critical-speed analysis shall be performed. Any lateral critical speed of a quill shaft shall be separated by at least 20 percent from any operating speed of any shaft in the system.

2.5.4 When torsional resonances are calculated to fall within the margin specified in 2.5.2 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse affect on the complete train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

2.6 Compressor Cylinders

2.6.1 GENERAL

2.6.1.1 The MAWP shall exceed the rated discharge pressure by at least 10 percent or 1.7 bar (25 pounds per square inch), whichever is greater. The MAWP shall be at least equal to the specified relief valve setting, not including accumulation. See 3.6.4.5.3 for the setting of relief valves.

2.6.1.2 Horizontal cylinders are required for compressing saturated gases or for gases carrying injected flushing liquids. All horizontal cylinders shall have bottom discharge connections.

Note: During certain atmospheric conditions, air may be at or close to saturated conditions; also, multi-stage air or hydrocarbon gas compressors will usually have saturated conditions following intercooling.

2.6.1.3 Cylinders shall be spaced and arranged to permit access for operating and removal for maintenance of all components (including water jacket access covers, distance piece covers, packing, valves, unloaders, or other controls mounted on the cylinder) without removing the cylinder, the process piping or pulsation suppressors.

2.6.1.4 Single acting, step piston, or tandem cylinder arrangements may be furnished with the purchaser's approval. For such cylinder arrangements, special consideration must be given to ensure rod reversals. See 2.4.4.

2.6.1.5 The use of tapped holes in pressure parts shall be minimized. To prevent leakage in 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.

2.6.2 CYLINDER APPURTENANCES

2.6.2.1 Cylinder supports shall be designed to avoid misalignment or excessive rod runout during the warm-up period and at actual operating temperature. The support shall not be attached to the outer end cylinder head. The pulsation suppressor shall not be used to support the compressor cylinder. The expected cold vertical rod runout shall be confirmed by the shop bar-over test and shown on the rod runout table (see Appendix C) by the vendor. The cold rod runout value shall provide an expected hot vertical rod runout not exceeding 0.00015 millimeter per millimeter (0.00015 inch per inch) of stroke.

The vendor shall calculate the vertical cold runout, including rod sag (as outlined in Appendix C or by other proprietary methods). These values and a runout table (see Appendix C) shall be submitted to the purchaser before the shop bar-over test. The shop-measured cold runout shall equal the predicted cold runout within a tolerance of ±0.00015 millimeter per millimeter (±0.00015 inch per inch) of stroke. Horizontal (side) piston rod runout, as measured by dial indicators during the shop bar-over test, shall not exceed 0.064 millimeter (0.0025 inch), regardless of length of stroke. See 4.3.4.1.

Refer to 2.8.6 when tail rod construction is used.

2.6.2.2 The vendor shall supply allowable nozzle-loading limits and diagrams at the vendor-supplied interface. These loadings shall be referred to an X, Y, Z coordinate system.

● **2.6.2.3** Unless otherwise specified, each cylinder shall have a replaceable, dry-type liner, not contacted by the coolant. The liner shall be at least 9.5 millimeters (⅜ inch) thick for piston diameters up to and including 254 millimeters (10 inches). For piston diameters larger than 254 millimeters (10 inches), the minimum liner thickness shall be 12 millimeters (½ inch).

Liners shall have an interference fit, and shall be held in place by other positive mechanical means, such as pins or a shoulder.

2.6.2.4 The walls of cylinders without liners shall be thick enough to provide for reboring to a total of 3.2 millimeters (⅛ inch) increase over the original diameter without encroaching on either the MAWP, or the maximum allowable continuous gas load, or the maximum allowable continuous combined rod loading.

2.6.2.5 The running bore of cylinder liners and cylinders without liners used for applications with metallic or nonmetallic wear bands and piston rings, for either lubricated or nonlubricated services, shall be within an arithmetic average roughness (R_a) value of 0.2–0.6 micrometer (8–24 microinches).

● **2.6.2.6** When specified, the running bore of the cylinder shall be coated with tetrafluoroethylene (TFE). The method of application shall be agreed on by the user and the vendor.

2.6.2.7 Cylinder heads, stuffing boxes for pressure packing, clearance pockets, and valve covers shall be fastened with studs. The design shall make it unnecessary to remove any studs in order to remove these component parts. Torque values for all studs and bolting shall be included in the manufacturer's instruction manual.

CAUTION: Exceeding the manufacturer's torque values may cause damage to the valve assembly and cylinder valve seat.

Where captured o-ring valve covers are used, two extra-long studs 180 degrees apart are to be provided for each cover to ensure the cover o-ring clears the cylinder valve-port bore before the valve cover clears the stud. Extra long studs shall be capable of having a full-threaded nut when the o-ring is clear of cylinder valve-port sealing bore.

2.6.2.8 Valve cage designs shall be of the cylindrical type held in place by a circular contact cover. Center-bolt or other through-bolt designs shall not be furnished. (See Appendix J for preferred approach.)

2.6.2.9 Valve port o-ring sealing surfaces shall not exceed an R_a of 1.6 micrometers (63 microinches). Valve ports using o-rings shall include an entering bevel for the o-ring.

2.6.2.10 Studded connections shall be furnished with studs installed. Blind stud holes should only be drilled deep enough to allow a preferred tap depth of 1½ times the major diameter of the stud; the first 1½ threads at both ends of each ANSI[12] Class 1, 2, and 3 fit stud shall be removed to allow the set end to bottom in the hole. Class 4 and 5 fit studs shall be installed with a depth gauge and shall not bottom in the holes. Anaerobic adhesive or similar epoxy bonding agents shall not be used with Class 1 or 2 fits.

2.6.2.11 Bolting shall be furnished as specified in 2.6.2.11.1 through 2.6.2.11.5.

2.6.2.11.1 Details of threading shall conform to ANSI B1.1. External fasteners subject to routine maintenance, fasteners for pressure retaining parts, and fasteners in cast iron shall be course thread series. Fasteners of diameters 24 millimeters (1 inch) and larger shall be of the constant 3 millimeter pitch (8 threads per inch) series.

2.6.2.11.2 Studs are preferred to cap screws.

2.6.2.11.3 Stud material shall be ASTM A 193 Grade B7 for steel and ductile iron cylinders. ASTM A 193 Grade B7 or ASTM A 307 Grade B may be used for cast iron cylinders. ASTM A 320 shall be used for temperatures of -30°C (-20°F) and below. ASTM material grade identification shall be located on the nut end of the exposed stud. With low temperature studs use ASTM A 194 Grade 4 or Grade 7 nuts. Acceptable nuts for use with ASTM A 193 or A 307 studs are ASTM A 194 Grade 2H.

2.6.2.11.4 Hex-head bolting is preferred. Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches. If extended studs are provided for hydraulic tensioning the exposed threads shall be protected by a cover.

2.6.2.11.5 Bolting on reciprocating or rotating parts shall be positively locked mechanically (lock washers, tab washers, and anaerobic adhesives are unacceptable as positive locking methods). See 2.8.1.

2.6.2.12 Valve chambers and clearance pockets shall be designed to minimize trapping of liquid.

2.6.2.13 If tapped drain connections are provided on external bottles used as clearance pockets, drain valves shall be provided (see section 3.7 for piping material between clearance pocket and drain valve).

2.6.3 CYLINDER COOLING

2.6.3.1 Cylinders shall have cooling provisions as required by the conditions of service described in 2.6.3.1.1 through 2.6.3.1.4 (refer to 3.7.4 and Figure G-1).

2.6.3.1.1 Static-filled coolant systems (see Figure G-1, Plan A) may be supplied where cylinders will not be required to operate fully unloaded for extended periods of time, the expected maximum discharge temperature is less than 90°C (190°F), and the rise in adiabatic gas temperature (difference between suction temperature and discharge temperature based on isentropic compression) is less than 85K (150F°).

2.6.3.1.2 Atmospheric thermosyphon coolant systems (see Figure G-1, Plan B) may be supplied where cylinders will not be required to operate while fully unloaded for extended periods of time and either (a) the expected maximum discharge temperature is between 90°C (190°F) and 100°C (210°F) or (b) the rise in adiabatic gas temperature is less than 85K (150F°).

2.6.3.1.3 By agreement of the purchaser and the vendor, a pressurized thermosyphon system may be used. The expected maximum discharge temperature is not to exceed 105°C (220°F). The system is to be supplied with a thermal relief valve set at a gauge pressure of 1.7 bar (25 pounds per square inch) maximum.

2.6.3.1.4 Forced liquid coolant systems (see Figure G-1, Plan C) shall be provided where cylinders will operate while fully unloaded for extended periods of time and either (a) the expected maximum discharge temperature is above 100°C (210°F) or (b) the rise in adiabatic gas temperature is 85K (150F°) or greater.

Note: For sites with ambient temperatures of 45°C (110°F) or higher, thermosyphon or static-filled systems may not be suitable. See 2.1.16 for fully unloaded extended operation.

2.6.3.2 Air-cooled cylinders shall not be furnished without the expressed written approval of the purchaser.

[12]American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

2.6.3.3 The cylinder cooling system provided shall be adequate to prevent gas condensation in the cylinder that may dilute or remove lubricant or may cause knocking. Guidelines for systems designs are as follows:

a. Coolant inlet temperatures shall be maintained at a minimum of 6K (10F°) above the inlet gas temperature. Lower inlet coolant temperatures may cause condensation of gas constituents.
b. Coolant flow and velocities should be sufficient to prevent solids suspended in the cooling media from falling out and causing the fouling of jackets and passages.
c. Coolant exit temperatures should not exceed 16K (30F°) above gas inlet temperature to avoid capacity reduction.

2.6.3.4 The cylinder cooling system shall be designed to positively prevent leakage of gas into the coolant. When cooling of cylinder heads is necessary, separate noninterconnecting jackets are required for cylinder bodies and cylinder heads.

● **2.6.3.5** When specified, a self-contained, forced circulation, closed jacket coolant system shall be furnished. It shall meet the requirements of 2.6.3.5.1 through 2.6.3.5.3. (Refer to Figure G-1, Plan D.)

2.6.3.5.1 The coolant supply to each cylinder jacket shall enter the jacket at a temperature at a minimum of 6K (10F°) above gas inlet temperature. A heating unit shall be provided as part of the self-contained closed jacket system for use during cold weather operation and for bringing the system up to temperature before start-up.

2.6.3.5.2 The coolant circulated shall be controlled to maintain a rise in coolant temperature across any individual cylinder, including the cylinder heads if cooled, of between 5K (10F°) and 10K (20F°).

2.6.3.5.3 The system shall be pre-piped, factory skid mounted, and complete with the various pressure and temperature indicators, alarms, and other instrumentation specified on the data sheets.

2.6.4 CYLINDER CONNECTIONS

2.6.4.1 The main inlet and outlet gas connections shall be flanged or machined and studded and shall be suitable for the working pressure of the cylinder as specified in 2.6.1.1.

Note: Flat faced flanges, in lieu of recessed or female face flanges, are required to permit removal of the cylinder without removing or springing piping or pulsation dampeners. Ring type joints (RTJ) and lens type joints should be discussed between the purchaser and vendor on a special requirement basis.

2.6.4.2 Studs shall be supplied unless cap screws are specifically approved by the purchaser.

2.6.4.3 The facing and bolting of the main inlet and outlet flanges and tapped auxiliary connections shall conform to the dimensional requirements of ASME B16.1, B16.42, or B16.5 as applicable. See 2.6.4.4 for facing finish requirements. The details of any special connections, such as a lens joint, shall be submitted to the purchaser for review (see Appendix F). For low-pressure cylinders, where noncircular elongated obround connections are used, the vendor is to supply inlet and discharge transition pieces with the termination flange to ANSI flange standards. The transition pieces shall be of the same grade of material as, or of a higher grade of material than the cylinder. The vendor is to supply all gaskets, studs, and nuts between the cylinder and transition piece.

2.6.4.4 The finish of the gasket contact surfaces of cast iron, ductile iron, or steel connections (flanged or machined bosses) other than ring-type joints shall be no less than 3.2 micrometers (125 microinches) R_a and no greater than 6.4 micrometers (250 microinches) R_a. Either a serrated-concentric finish or a serrated-spiral finish having 9–16 grooves per centimeter (24–40 grooves per inch) shall be used. The surface finish of the gasket grooves of ring joint connections shall conform to ASME B16.5. Surface finish shall be inspected by comparator.

2.6.4.5 Process gas connections shall be flanged or machined and studded. For utilities, threaded connections are permissible in sizes NPS 3/4 to NPS 1 1/2.

● **2.6.4.6** Each cylinder shall be provided with an NPS 1/2 indicator tap at each end for gauge pressures less than 350 bar (5000 pounds per square inch) and, when specified, for gauge pressures of 350 bar (5000 pounds per square inch) and higher. Designs similar to Figure G-2, with a corrosion-resistant sleeve arrangement inside a continuous cast-in membrane to provide a positive gas-tight seal, are acceptable for cast iron and nodular iron cylinders. Materials shall be compatible with the gas. Unless indicator valves are specified by the purchaser, tapped holes shall be plugged in accordance with 3.7.1.12.

2.7 Valves and Unloaders

2.7.1 Average valve gas velocity shall be computed in metric units as shown in Equation 1:

$$W = \frac{Fc_m}{f} \tag{1}$$

And in U.S. customary units:

$$V = 288\frac{D}{A}$$

Where:

W = average gas velocity, in meters per second.
F = piston area, the area of the crank-end of the cylinder less the piston rod plus the area of the outer end of the piston, in square centimeters.

f = product of the actual lift, the valve-opening periphery, and the number of inlet or discharge valves, in square centimeters.
c_m = average piston speed, in meters per second.
V = average gas velocity, in feet per minute.
D = piston displacement per cylinder, in cubic feet per minute.
A = product of the actual lift, the valve-opening periphery, and the number of inlet or discharge valves per cylinder, in square inches.

Note: The valve lift used in Equation 1 shall be shown on the data sheets.

If the lift area is not the smallest area in the flow path of the valve, that condition shall be noted on the data sheet, and the velocity shall be computed on the basis of the smallest area. Velocities calculated from Equation 1 should be treated only as a general indication of valve performance and should not be confused with effective velocities based on crank angle, degree of valve lift, unsteady flow, and other factors. The velocity computed from Equation 1 is not necessarily a representative index for valve power loss or disk/plate impact.

2.7.2 Valve and unloader designs shall be suitable for operation with all gases specified. Each individual unloading device shall be provided with a visual indication of its position and its load condition (loaded or unloaded).

2.7.3 The valve design, including that for double-decked valves, shall be such that valve assemblies cannot be inadvertently interchanged or reversed. For example, it shall not be possible to fit a suction valve assembly into a discharge port, nor a discharge valve assembly into a suction port; nor shall it be possible to insert a valve assembly upside down.

2.7.4 Valve assemblies (seat and guard) shall be removable for maintenance. Valve-seat-to-cylinder gaskets shall be solid metal or metal jacketed. Valve-cover-to-cylinder gaskets shall be either solid metal, the flexible graphite type, metal jacketed, or the o-ring type. Other gasket types may be used with mutual agreement between the purchaser and the vendor.

Note: Flexible graphite-type gaskets with a suitable reinforcement have been successfully used to seal valve cover to cylinder gaskets where low mole weight gases are compressed.

2.7.5 The valve and cylinder designs shall be such that neither the valve guard nor the assembly bolting can fall into the cylinder even if the valve assembly bolting breaks or unfastens.

2.7.6 When discharge valve assemblies weigh 15 kilograms (35 pounds) or more, the vendor shall provide a device to facilitate removal and installation of valve assemblies for maintenance. On all under-slung valves above 150 millimeters (6 inches) in diameter, an arrangement shall be provided to hold the complete valve assembly and any cage in position while the cover is installed.

2.7.7 The ends of coil-type valve springs shall be squared and ground to protect the plate against damage from the spring ends.

2.7.8 Valve hold-downs shall bear at not less than three points on the valve assembly. The bearing points shall be arranged as symmetrically as possible (refer to 2.6.2.8).

● **2.7.9** The vendor shall conduct a computer study of the valve dynamics to optimize the valve design for efficiency, reliability, and life. The analysis shall model the valve elements, spring stress, aerodynamic drag coefficients, fluid damping, flow through the valve during the compression cycle, and any other factors deemed necessary by the vendor to assess valve element motion, impact, and efficiency. This study shall review all operating gas densities and load conditions.

When specified, the vendor shall submit a written valve dynamics report to the purchaser.

2.7.10 Metal valve disks or plates, when furnished, shall be suitable for installation with either side sealing and shall be finished on both sides to an R_a of 0.4 micrometer (16 microinches) or better. Edges shall be suitably finished to remove stress risers. Valve seats and sealing surfaces shall also be finished to an R_a of 0.4 micrometer (16 microinches) or better. When thermoplastic valve plates or disks are furnished, flatness and surface finish shall be controlled so that adequate sealing occurs in operation. When Poly Ether Ether Ketone (PEEK) plates are furnished, the grade must be crystalline.

Note: PEEK valve plates have been used successfully to a gauge pressure of 135 bar (2000 pounds per square inch) and 180°C (350°F).

● **2.7.11** When specified, valve seats for use with metallic valve plates shall have a minimum finished hardness of Rockwell C32 and shall be either through-hardened or induction-hardened to a minimum case depth of 1.6 millimeters (1/16 inch). See 2.14.1.10.

● **2.7.12** When cylinder unloading is specified, it shall be accomplished by either valve depressors or plug-type unloaders. Valve assembly lifters shall not be used. When valve depressors are used for capacity control, all inlet valves of the cylinder end involved shall be so equipped where possible. Use of less than a full complement of suction valve depressors requires the purchaser's approval. When specified, a protective sheet metal rain shield shall be furnished to protect exposed topside unloader parts from the elements, and the rain shield shall be corrosion resistant and shall be fabricated with a handle for easy removal and replacement. See Appendix J for a sketch of the rain cover.

Note: Special precautions may be necessary when using valve plate depressors in combination with non-metallic valve plates or discs.

2.7.12.1 Where plug-type unloaders are used for capacity control, the number of unloaders is determined by the area per plug opening, the total of which must be equal to or greater than half of the total free lift area (or least flow area) of all suction valves on that end. The unloader assembly shall positively guide the plug to the seat.

2.7.12.2 When valve depressors are used only for start-up, and never for capacity control, consideration shall be given to using a reduced number of unloaders. For start-up with plug unloaders, only one per cylinder end is needed.

2.7.12.3 Unless otherwise specified, pneumatically operated unloaders shall be used. Individual hand-operated unloaders or manual overrides on pneumatically operated unloaders are not permitted. Automatic operated unloaders shall be piped by the manufacturer in such a manner that inadvertent operation between stages and cylinder ends shall not occur. The vendor shall provide the user with information regarding the proper sequencing for unloader operation. See 3.6.2.2.

2.7.13 Pneumatic unloaders shall be designed so that the air used for unloading cannot mix with the gases being compressed, even in the event of failure of the diaphragm or another sealing component. A threaded gas vent connection shall be provided at the stem packing.

Unloader sliding push rods exposed to atmospheric conditions shall be of corrosion-resistant material.

2.8 Pistons, Piston Rods, and Piston Rings

2.8.1 Pistons that are removable from the rod shall be attached to the rod by a shoulder-and-locknut design or by a multi-through-bolt design. All nuts must be positively locked in place. See 2.6.2.11.5. Locking nuts attaching the piston rod to the piston and to the crosshead shall be tightened in accordance with the manufacturer's standard. The rod shall be positively locked to the crosshead to prevent rotation. As a minimum, the manufacturer's tightening procedure must assure a minimum thread-root pre-stress level of 1½ times the rod's thread-root stress at maximum allowable continuous rod loading. Hydraulic or thermal methods are preferred for tightening piston-rod nuts when the rod diameter is 75 millimeters (3 inches) or larger. Use of slugging-type wrenches is unacceptable for this purpose.

2.8.2 Hollow pistons (single piece or multi-piece) shall be continuously self-venting; that is, they shall depressure when the cylinder is depressured. Acceptable methods of venting are a hole located in the head-end face of the piston in the form of a single hole 3 millimeters (⅛ inch) in diameter, a hole at the bottom of the piston ring groove, or a spring-loaded relief plug in the outer-end face of the piston.

2.8.3 Wear bands, if required by the manufacturer or specified by the purchaser, shall be of single- or multi-piece construction designed to prevent underside pressurization (action similar to a piston ring). If feasible, pistons shall be segmented to facilitate wear band installation. Piston ring carriers for multi-piece pistons shall be furnished of wear resistant material. Nonmetallic wear bands shall not overrun fully open single-hole valve ports or liner counterbores by more than half the width of the wear band. Where the cylinder design requires the wear band to overrun the valve ports by more than half the band width, the port design shall be of the multiple-drilled-hole type to provide sufficient support for the wear band. For nonlubricated service, the bearing load of nonmetallic wear-bands shall not exceed 0.035 newtons per square millimeter (5 pounds per square inch) based on the weight of the entire piston assembly plus half the weight of the rod divided by the projected area of a 120-degree arc of all wear bands (0.866 DW, where D is the piston diameter and W is the total width of all wear bands).

For lubricated service, the bearing load on wear bands, if used, shall not exceed 0.07 newtons per square millimeter (10 pounds per square inch) based on the same criteria.

Note: At a gauge pressure below 14 bar (200 pounds per square inch), loadings of up to 0.05 newtons per square millimeter (7 pounds per square inch) have been successfully used for large nonlubricated cylinders.

In general, nonlubricated construction units will have higher wear rates than lubricated construction.

2.8.4 All piston rods, regardless of base material, shall be continuously coated from the piston-rod packing to the oil wiper packing travel areas with a wear resistant material.

The coating material and base material shall be agreed on by the purchaser and the vendor. The coating material must be properly sealed to prevent corrosion of the base material at the interface of the coating. Fusion techniques that require temperatures high enough to affect the mechanical characteristics of the base material are unacceptable.

Piston-rod base material and coatings for use in corrosive environments shall be suitable for the service and operating conditions specified on the data sheets.

Note 1: High-velocity and high-impact thermal coating processes are acceptable for the coating of piston rods. Metal spray techniques requiring roughening of the surface of the base metal are not recommended, because of the potentially destructive stress risers left in the surface. Use of subcoating under the main coating is not recommended.

Note 2: Piston rods that have been previously induction-hardened are not to be coated with a wear resistant material over the induction-hardened case.

2.8.4.1 Piston rods of AISI 4140 steel used in sour gas service shall have an entire through-hardness not exceeding Rockwell C22. See 2.14.1.10.

2.8.4.2 Typical tolerances for finished rods are 12.5 micrometers (0.0005 inch) for roundness and 25 micrometers (0.001 inch) for diametrical variation over the length of the rod.

The surface finish in the packing areas for lubricated and nonlubricated services shall be an R_a of 0.20–0.40 micrometer (8–16 microinches) for a cylinder MAWP up to a gauge pressure of 420 bar (6000 pounds per square inch).

2.8.5 Piston rods shall be furnished with rolled threads having polished thread relief area. The vendor shall state on the data sheets the rod material, the yield strength, and the stress at the thread-root diameter at the maximum allowable continuous piston-rod loading.

2.8.6 Tail rods shall be used only with the purchaser's specific approval. Tail rod packing assemblies shall be equal in design and quality to packing assemblies for piston rods. Tail rod surface coating in the packing travel area shall be in accordance with 2.8.4. Tail rod design shall include a tail rod retaining device. Rod runout measured at the tail rod packing assembly shall not exceed the limits defined in 2.6.2.1.

2.9 Crankshafts, Connecting Rods, Bearings, and Crossheads

2.9.1 Crankshafts shall be forged in one piece (but may have provision for removable counterweights) and shall be heat-treated and machined on all working surfaces and fits. They shall be free of sharp corners. Main and crankpin journals shall be ground to size. Drilled holes or changes in section shall be finished with generous radii and shall be highly polished. Forced lubrication passages in crankshafts shall be drilled. See 4.2.2.3.3 for ultrasonic testing of crankshafts.

2.9.2 Replaceable, precision-bored shell (sleeve) crankpin bearings and main bearings shall be used; however, tapered roller type anti-friction bearings are acceptable for main bearings in compressors with nominal frame ratings of 150 kilowatts (200 horsepower) or less. Cylindrical, roller or ball type anti-friction bearings are unacceptable.

2.9.3 All tapered roller-type anti-friction bearings shall be suitable for belt drives and shall give an L_{10}-rated life (see AFBMA Standard 11) of either 50,000 hours with continuous operation at rated conditions or 25,000 hours at maximum axial and radial loads and rated speed. (The rating life is the number of hours at rated bearing load and speed that 90 percent of the group of identical bearings will complete or exceed before the first evidence of failure.)

2.9.4 Tapered roller type, anti-friction bearings shall be retained on the shaft and fitted into housings in accordance with the applicable AFBMA publications.

2.9.5 Connecting rods shall be forged steel with removable caps. They shall be free of sharp corners. Forced lubrication passages shall be drilled. Drilled holes or changes in section shall be finished with generous radii and shall be highly polished. Crankpin bushings shall be of the replaceable precision-bored type and shall be securely locked in place. All connecting rod bolts and nuts shall be securely locked with cotter pins or wire after assembly. Connecting rod bolts shall have rolled threads.

2.9.6 Crossheads for horizontal compressors with nominal frame ratings greater than 150 kilowatts (200 horsepower) shall be steel. ASTM A 536 Grade 80-55-06 ductile iron is acceptable for crossheads in frames nominally rated at 150 kilowatts (200 horsepower) or less. Replaceable, shim-adjustable top and bottom shoes shall be provided. Adequate openings shall be provided to service crosshead assemblies.

● **2.9.7** If specified, the crankcase shall be provided with relief devices to protect against rapid pressure rises. These devices shall incorporate downward-directed apertures (away from the operator's face), a flame-arresting mechanism, and a rapid closure device to minimize reverse flow. Sizing of these devices must follow the sizing criteria outlined by the British Internal Combustion Engine Research Association (BICERA).

2.9.8 When not an integral part of the frame, crosshead housings shall be attached to the crankcase with studs. A metal-to-metal joint, prepared with suitable sealant, shall be used between the crosshead housing and crankcase, the crosshead housing and distance piece, and the distance piece and cylinder.

2.10 Distance Pieces

● **2.10.1** The purchaser will indicate on the data sheets which type of distance piece listed in 2.10.1.1 through 2.10.1.4 is required (see Figure G-3).

2.10.1.1 *Type A—Short single-compartment distance piece used for lubricated service only where oil carry-over (at the wiper packing and pressure packing) is not objectionable.* This arrangement shall not be used when cylinders are lubricated with synthetic oils.

Note: Type A distance pieces are used only for nonflammable or nonhazardous gases.

2.10.1.2 *Type B—Long single-compartment distance piece used for nonlubricated service or when specified on the data sheets.* It shall be of sufficient length to prevent oil carry-over. No part of the piston rod shall alternately enter the crankcase (crosshead housing) and the gas cylinder pressure packing. The rod shall be fitted with an oil slinger of spark resistant material and preferably of a split design for easy access to the piston-rod packing.

2.10.1.3 *Type C—Long/long two-compartment distance piece designed to contain flammable, hazardous, or toxic gases.* No part of the piston rod shall alternately enter the wiper packing, intermediate partition packing, and the cylinder pressure packing.

Segmental packing shall be provided between the two compartments. Provisions for lubrication of this segmental packing, if necessary, shall be furnished by the vendor.

Note: The Type C distance piece with two oil slingers, one in each compartment, is not normally used on process compressors. This type of distance piece is used only for special services such as oxygen service. This distance piece design causes the overall length of the gas end assembly to become excessively large, thus causing the overall width of the compressors to become large, and therefore increasing foundation requirements. Uses of such distance pieces can cause piston-rod diameters to increase, because of the column effect of excessively long piston rods.

2.10.1.4 *Type D—Long/short two-compartment distance piece designed to contain flammable, hazardous, or toxic gases.* No part of the piston rod shall alternately enter the wiper packing and the intermediate seal packing. Segmental packing shall be provided between the two compartments. Provisions for lubrication of this segmental packing, if necessary, shall be furnished by the vendor.

● **2.10.2** Access openings of adequate size shall be provided in all distance pieces to permit removal of the assembled packing case. On Type D two-compartment distance pieces, the compartment adjacent to the cylinder (the outboard compartment) may be accessible through a removable partition. Distance pieces (or compartments) shall be equipped with screened safety guards, louvered weather covers, or gasketed solid metal covers as specified on the data sheet.

All access openings shall be surfaced and drilled to accommodate solid metal covers. Nonmetallic covers are not permitted.

2.10.3 Distance piece design shall be such that the packing rings can be removed and replaced without removal of the piston rod.

2.10.4 Where solid metal distance piece covers are provided or specified, distance piece, partitions, covers, bolting, and the intermediate partition packing shall be designed for a compartment differential pressure of 2 bar (25 pounds per square inch) or higher, if specified. The vendor shall indicate the MAWP of the distance piece on the data sheet.

2.10.5 Each distance piece compartment shall be provided with a bottom drain connection and a top vent connection for the purchaser's piping. A distance piece compartment with internal reinforcing ribs shall have internal drain provisions through the ribs. A separate top vent or purge connection shall be provided for each distance piece compartment. Vent connections shall be at least NPS 1½. Refer to Appendix I for vent and purge system schematics. All other external connections shall be at least NPS 1. Internal packing vent tubing and fittings shall be of AISI Standard Type 300 stainless steel. A packing vent connection shall be provided below the rod to facilitate liquid draining of the packing case. Where packing case cooling is required or specified, the inlet connection shall be provided on the bottom of the distance piece and the outlet connection shall be provided on the top of the distance piece. See Figure G-3.

Unless otherwise specified, all external drain, vent, and purge piping and equipment shall be provided by the purchaser. Closed, sealed, or purged distance pieces not utilizing the NPS 1½ free vent connection shall be equipped with a relief device having an area at least equal to the area of the hole through the crank-end-head piston-rod hole minus the area of the piston rod.

The vendor shall confirm that the NPS 1½ free vent connection or relief device is adequate to prevent overpressure of the distance piece in the event of a packing case failure.

2.10.6 For Types A and B distance pieces with solid metal covers, positive seal rings shall be provided at the wiper packings. For Types C and D distance pieces with solid metal covers, positive seal rings shall be provided at both the wiper packings and the intermediate partition packings. These seal rings shall be of the segmental type that will seal to prevent contamination of the crankcase oil by leakage from the cylinder pressure packing. Refer to 2.11.8.

2.11 Packing Case and Pressure Packing

● **2.11.1** All oil-wiper packings, intermediate partition packings, and cylinder pressure packings shall be segmental rings with garter springs of a nickel chromium alloy (such as Inconel 600 or X 750). When specified, shields shall be provided in the crosshead housings over the oil return drains from the wiper-packing stuffing boxes to prevent splash flooding.

2.11.2 Packing case flanges shall be bolted to the cylinder head or to the cylinder with no less than four bolts. Flanges shall be of steel for flammable, hazardous, or toxic gas service. Packing cases shall be pressure rated at least to the MAWP of the cylinder. Packing case assemblies shall have positive alignment features, such as cup-to-cup pilot fits and/or sufficient body-fitted tie bolts.

2.11.3 For flammable, hazardous, toxic, or wet gas service, the pressure packing case shall be provided with a common vent and drain, below the piston rod, piped by the vendor to the lower portion of the distance piece. See Appendix G.

2.11.4 Unless otherwise specified on the data sheets, the criteria given in 2.11.4.1 through 2.11.4.4 shall be followed for the cooling of pressure packing cases.

2.11.4.1 The manufacturer's standard design may be used for cylinder discharge gauge pressure to 100 bar (1500 pounds per square inch).

2.11.4.2 Liquid-cooled packing cases with totally enclosed cooled cups are required when the following packing materials are used:

a. Nonlubricated, nonmetallic packing rings, when the MAWP of the cylinder is above a gauge pressure of 17 bar (250 pounds per square inch).
b. Lubricated, nonmetallic rings, when the cylinder MAWP is above a gauge pressure of 35 bar (500 pounds per square inch).

c. All materials, lubricated or nonlubricated, when the cylinder MAWP is above a gauge pressure of 100 bar (1500 pounds per square inch).

2.11.4.2.1 O-rings shall be used to seal coolant passages between cups. O-rings shall be fully captured in grooves, both on the inside diameter and the outside diameter of the o-ring. A small relief recess of 0.5–1 millimeter (0.015– 0.030 inch) shall be provided around the captured o-ring groove to the outside diameter to prevent gas from pressuring the o-ring and to detect leakage. O-rings that span the piston rods are not allowed below a gauge pressure of 135 bar (2000 pounds per square inch).

2.11.4.2.2 Liquid-cooled cases shall be tested for leakage on the coolant side to a gauge pressure of 8 bar (115 pounds per square inch).

2.11.4.3 Packing cases for pressure packings of all nonlubricated compressors that have a cylinder MAWP below a gauge pressure of 17 bar (250 pounds per square inch) shall be suitable for liquid cooling and shall be plugged with threaded steel plugs at the packing case.

2.11.4.4 When the packing case is cooled by forced circulation, the vendor shall supply a suitable filter having a 125-micrometer (125-micron) nominal rating or better, and located external to the distance piece. (See the note under 2.12.6 for the definition of *nominal.*) Internal tubing and forged fittings of AISI Standard Type 300 stainless steel shall be furnished by the vendor.

If external tubing is provided by vendor, it shall be AISI Standard Type 300 stainless steel.

● **2.11.5** When cooling of packing is required, the vendor shall be responsible for determining minimum requirements—such as flow pressure, pressure drop, and temperature—and any filtration and corrosion protection criteria and shall also be responsible for informing the purchaser of these requirements. The coolant pressure drop through the packing case shall not exceed 1.7 bar (25 pounds per square inch).

If specified, the vendor shall supply a closed liquid cooling system. This system shall always be separate from the cylinder jacket cooling system. Refer to Appendix G, Figure G-4, for additional details on self-contained cooling systems for packing.

Note: The inlet coolant temperature to the packing case should not exceed 35°C (90°F). Packing efficiency is improved with low coolant temperature.

2.11.6 Adequate radial clearance shall be provided between the piston rod and all adjacent stationary components to prevent contact when the maximum allowable wear occurs on the piston wear bands.

2.11.7 Crosshead packing boxes shall employ wiper packing to effectively minimize oil leakage from the crankcase.

● **2.11.8** When specified to reduce process gas emissions to an absolute minimum, the cylinder pressure-packing case shall include venting and inert buffer gas cups with wedge-type packing rings in the adjacent sealing cups. See the arrangement in Appendix I, Figure I-1.

2.11.9 Entering sleeves shall not be used for installation of piston rods through packing cases. When the outside diameter of the entering sleeve is equal to the outside diameter of the rod, entering sleeves may be used with the purchaser's approval.

2.12 Compressor Frame Lubrication

2.12.1 The frame lubrication system shall be a pressurized system; however, splash lubrication systems may be used on horizontal compressors with antifriction journal bearings when the compressor's nominal frame rating is 150 kilowatts (200 horsepower) or less. The crankcase oil temperature shall not exceed 70°C (160°F) for pressurized oil systems and 80°C (180°F) for splash systems. Cooling coils shall not be used in crankcases or oil reservoirs.

2.12.2 If specified, pressure lubrication systems shall be designed and furnished in accordance with API Standard 614.

Note: API Standard 614 is typically applied only to reciprocating compressor trains involving a large turbine driver and gear unit.

2.12.3 All pressure lubrication systems shall, as a minimum, consist of an oil pump with a suction strainer, a supply-and-return system (see 3.7.2), an oil cooler (when required), a full-flow filter, and other necessary instruments. (Refer to Appendix G, Figure G-5, for a typical schematic drawing of a lube-oil system). The requirements of 2.12.3.1 through 2.12.3.5 shall apply.

2.12.3.1 All external oil-containing pressure components, including auxiliary pumps, shall be steel, except that crankshaft-driven lube-oil pumps may have cast iron or nodular iron casings.

● **2.12.3.2** For each unit having a nominal frame rating of more than 150 kilowatts (200 horsepower), the compressor manufacturer shall provide a separate, independently driven, full-capacity, full-pressure auxiliary oil pump with an automatic start feature activated by low lube-oil pressure and shall include provisions for postlubrication after shutdown. The type of driver will be specified on the data sheets. Unless otherwise specified, pump drivers shall be sized for the pump power and the required starting torque at an oil viscosity of 1100 centistokes.

● **2.12.3.3** Both main and auxiliary pumps shall be sized for 20-percent greater flow than the total required oil demand. In addition, each pump shall be provided with a separate nonintegral pressure relief valve individually piped back to the crankcase reservoir. A relief valve serving the main oil pump may have a cast iron or nodular iron body if it is located inside the crankcase; otherwise it shall be steel. When specified by the purchaser, the relief valve for the crankcase-driven pump shall be mounted outside the crankcase.

2.12.3.4 The rated pressure for the frame lubrication system shall be a gauge pressure of 10 bar (150 pounds per square inch) minimum.

2.12.3.5 Lube-oil consoles shall have a steel baseplate with a rim and drip lip for drainage.

● **2.12.4** An oil cooler shall be provided to maintain the oil supply temperature at or below 55°C (130°F). The cooler shall be a water-cooled, shell-and-tube type or a suitable air-cooled type, as specified. Shell-and-tube coolers shall have water on the tube side. A removable-bundle design is required with coolers with more than 0.5 square meter (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 16 millimeters (5/8 inch) and the tube wall shall have a thickness of not less than 18 BWG [1.2 millimeters (0.049 inch)]. Unless otherwise specified, cooler shells, channels, and covers shall be steel; tube sheets shall be brass; and tubes shall be admiralty. U-bend tubes are not permitted. Each cooler shall be sized to accommodate the total cooling load. To prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure. Coolers shall be equipped with vent and drain connections on their oil and water sides. The vendor shall include in the proposal complete details of any proposed air-cooled cooler. Internal oil coolers are not acceptable.

2.12.5 An oil temperature control valve of flanged steel construction shall be provided to maintain constant oil temperature to the compressor. The valve shall control temperature by regulating the flow of oil through and around the cooler and shall have a manual override. (Refer to Appendix G, Figure G-5, for a typical schematic drawing of an oil system).

● **2.12.6** Full-flow filters with replaceable elements shall be supplied, with filtration of 10 microns (nominal) or finer. The filters shall be located downstream of the cooler. Filters having covers weighing more than 16 kilograms (35 pounds) shall have cover lifters. Filters shall not be equipped with a relief valve or an automatic bypass. Filter cartridge materials shall be corrosion resistant. Metal-mesh or sintered-metal filter elements are unacceptable. Flow shall be from the outside toward the center of the filter cartridge. The design of the filter-cartridge assembly shall assure that internal bypassing cannot occur because of filter-to-cartridge or cartridge-to-cartridge misalignment, inadequate end cover sealing design, or other sealing deficiencies. The pressure drop for clean filter elements shall not exceed 0.3 bar (5 pounds per square inch) at an operating temperature of 40°C (100°F) and normal flow. Cartridges shall have a minimum collapsing differential pressure of 5 bar (70 pounds per square inch). Each filter shall be equipped with a vent and with clean- and dirty-side drain connections. The maximum allowable working pressure of the filter casing shall not be less than the system relief valve setting. The relief valve setting shall be no greater than the sum of the normal bearing supply pressure, the equipment and piping losses upstream of the filter, and the cartridge collapsing differential pressure at a minimum oil temperature of 27°C (80°F) and the normal flow rate to the bearings. A thermal relief valve shall be provided for each filter housing. For start-up oil temperatures below 27°C (80°F), a heater in accordance with 2.12.7 shall be supplied. When specified, dual filters shall be supplied complete with a separate or integral continuous-flow transfer valve that provides tight shutoff of the idle filter. The system shall be designed to permit cartridge replacement and repressurizing during operation.

Note: Micron particle size implies the shape of a spherical bead; thus, a 10-micron particle is a sphere with a diameter of 10 microns. Within the element's recommended maximum pressure drop, 10 microns nominal implies that the efficiency of the filter on particles that are 10 microns or larger in diameter will be no less than 90 percent for the life of the element. Absolute micron particle ratings are different. A micron absolute filter rating implies that no particles of the rating size or larger will pass; for example, a filter may be 10 microns nominal and 15 microns absolute.

● **2.12.7** When specified, a removable steam-heating element external to the reservoir or a thermostatically controlled electric immersion heater with a sheath of AISI Standard Type 300 stainless steel shall be provided for heating the charge capacity of oil before start-up in cold weather. The heating device shall have sufficient capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start-up temperature within 12 hours. If an electric emersion heater is used, the watt density shall not exceed 2.0 watts per square centimeter (15 watts per square inch).

2.12.8 The oil reservoir shall be equipped with an oil-level sight glass. The maximum and minimum operating levels shall be permanently indicated.

2.13 Cylinder and Packing Lubrication

2.13.1 GENERAL

● **2.13.1.1** The purchaser will specify either a single plunger-per-point system or a divider block mechanical lubricator system for compressor and packing lubrication.

2.13.1.2 Lubricators shall be driven by the crankshaft or driven independently as specified. Lubricators shall be separate from the frame lubricating pump(s) and complete with the necessary tubing or piping (see 3.7.3). Ratchet lubricator drives are unacceptable.

2.13.1.3 Pumps shall be sized to permit a 100-percent increase and a 25-percent decrease in design flow.

● **2.13.1.4** When specified, a heating device with thermostatic control for the lubricator reservoir oil shall be provided. The watt density of the device shall be limited to 2.0 watts per square centimeter (15 watts per square inch). The size of the heating system and temperature control instrumentation shall be as agreed on by the purchaser and the buyer.

Note: When an internal heater is used it shall be fully immersed even at minimum level. (See 2.13.2.4.)

2.13.1.5 Unless otherwise specified, lubricators shall have provisions for prelubrication of the compressor before compressor start-up.

● **2.13.1.6** Alarm functions shall be provided, if specified, by the purchaser.

2.13.1.7 A lubrication point (or points) shall be provided for each compressor cylinder bore and packing. A stainless steel integral double-ball check valve rated at a minimum gauge pressure of 551.6 bar (8000 pounds per square inch) shall be provided as close as possible to each lubrication point.

2.13.1.8 Lube-oil injection passages to the cylinder bore shall be drilled through metal provided in the cylinder water jacket casting or weldment. Lubrication pipes or tubes (similar to those in Appendix G, Figure G-2) running through that metal in the water jacket are acceptable. Pipe or metal tubing shall be AISI Standard Type 300 stainless steel as a minimum and may be used in the gas passages if the materials are compatible with the gas composition (see 3.7.3). Lube-oil injection passages shall be drilled and tapped for all cylinders including those in nonlubricated services. Unused holes shall be plugged with threaded stainless steel solid plugs. Tubing connections shall be match-tagged for identification at the disassembly points for all compressor components, to facilitate reassembly.

● **2.13.1.9** The purchaser will indicate whether the compressor cylinders will be lubricated by synthetic lubricants. The lubricant specifications will be entered on the data sheet by the purchaser unless the vendor's recommendation is desired. All gaskets, seals, unloader diaphragms, packing, lubricator parts, and other parts coming into contact with the synthetic lubricant shall be of compatible materials agreed on by the compressor manufacturer and the lubricant manufacturer. Where possible, interior surfaces coming in contact with a synthetic lubricant shall be left unpainted. If interior surfaces (of distance pieces, for example) must be painted, a synthetic-lubricant-resistant coating recommended by the lubricant manufacturer shall be used.

2.13.2 POINT-TO-POINT LUBRICATION

2.13.2.1 Lubricators shall have a sight-flow indicator for each lubrication point.

2.13.2.2 The feed rate to each point shall be individually adjustable while the compressor is operating.

2.13.2.3 Reservoir capacity shall be adequate for 30 hours of operation at normal flow.

2.13.2.4 Protection against failure of the cylinder and packing lubricators shall consist of a low-pressure alarm connected to the discharge of an extra plunger pump that circulates oil through an orifice and back to the lubricator reservoir. This pump shall have its suction tube shortened so that it will lose suction when the lubricator reservoir oil drops to below 30 percent of full level. When more than one reservoir compartment is used, each compartment shall be so protected.

2.13.3 DIVIDER BLOCK LUBRICATION

● **2.13.3.1** The method of prelubrication shall be agreed on by the purchaser and the vendor.

2.13.3.2 The pumping rate shall be adjustable while the compressor is operating.

● **2.13.3.3** Each outlet of the primary divider block shall be equipped with a resetable spring-loaded indicator pin for indicating when the outlet is plugged. The system shall be protected from overpressure with a rupture disk located downstream of the pump(s). A pressure gauge shall also be provided indicating pump discharge pressure. For protection against loss of flow, a cycle monitor shall be provided with a digital display showing total flow and shall be equipped with an alarm that indicates low flow. The cycle monitor shall be driven by a proximity switch mounted on the primary divider block. Additional protection shall be provided as agreed on by the purchaser and the buyer.

2.14 Materials

2.14.1 GENERAL

● **2.14.1.1** 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.

Appendix H lists general material classes for the compressor which, when used with appropriate heat treatment and/or impact-testing requirements, will ensure the supply of materials generally considered acceptable for major component parts. See 3.7 for requirements for auxiliary piping materials. The metallurgy of all major components shall be clearly stated in the vendor's proposal.

2.14.1.2 Materials shall be identified in the proposal with the applicable ASTM, AISI, or ASME numbers, including material grade, or by reference to appropriate international standards. When no such designation is available, the vendor's material specification, giving mechanical properties, chemical composition, and test requirements, shall be included in the proposal.

2.14.1.3 The vendor shall specify the ASTM optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service. These tests and inspections shall be listed in the proposal and reviewed at the coordination meeting. The purchaser may consider specifying additional tests and inspections, especially for materials used in critical components.

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

2.14.1.5 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.

● **2.14.1.6** It is the responsibility of the purchaser to note on the data sheet the presence and maximum amounts of corrosive, reactive, or hazardous agents or components in the process fluids or in the environment such as the following: hydrogen sulphide; chlorides or other constituents which may cause corrosion-related cracking; constituents which may be reactive with copper or copper alloys.

2.14.1.7 Copper and copper alloys shall not be used for parts of compressors or auxiliaries in contact with corrosive gas or with gases capable of forming explosive copper compounds. Nickel-Copper Alloy (UNS N04400 [Monel or its equivalent]), bearing babbitt, and precipitation-hardened stainless steels are excluded from this requirement. Where agreed on by the vendor and the purchaser, copper-based materials may be used for packing on lubricated compressors.

2.14.1.8 Parts that are manufactured from austenitic stainless steel, that are subjected to welding (for fabrication, hardfacing, overlay, or repair), and that are exposed to chlorides or other conditions that promote intergranular corrosion shall be manufactured from a low-carbon or stabilized grade or shall be solution-annealed after welding.

Note: Overlays or hard-facings 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.

CAUTION: If chloride exists in the process gas stream to any extent, extreme care must be taken in selecting materials to be in contact with the process gas. Caution should be taken in using components of aluminum and AISI Standard Type 300 series stainless steel.

2.14.1.9 All materials of construction in contact with process gases shall be compatible with the gases handled. The corrosion allowance for separate carbon steel knockout pots shall be a minimum of 3.2 millimeters ($^1/_8$ inch). The corrosion allowance for heat exchangers and alloy parts required for special services shall be agreed on by the purchaser and the vendor.

2.14.1.10 All materials exposed to H_2S gas service as defined by NACE MR0175 shall be in accordance with the requirements of that standard.

Components that are fabricated by welding shall be stress relieved, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements.

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

In many applications, small amounts of H_2S are sufficient to require NACE materials.

When trace quantities of H_2S are present, or the amount of H_2S is uncertain, then the purchaser should automatically note on the data sheet that NACE materials are required.

Components to which NACE requirements apply shall include, as a minimum, the following: all pressure-containing cylinder parts (such as the cylinder, heads, clearance pockets, valve covers); all components within the cylinder (such as piston, piston rod, valves, unloaders, fasteners); all components within the outboard distance piece (such as packing box, packing, fasteners); and all external fasteners (except frame fasteners). See Appendix P.

External fasteners to which NACE material requirements apply shall include the following: all bolting on the exterior of the cylinder that retains gas-pressure-containing parts (such as valve covers, unloaders, heads, clearance pockets, piping connections); bolting that holds the cylinders to the distance piece; bolting that joins distance piece components; bolting that holds the distance piece to the crosshead guide; bolting that holds the crosshead guide to the frame; and bolting on distance piece covers. On multiple cylinder machines, NACE requirements shall apply to all cylinders.

Exceptions to NACE requirements for hardness are acceptable for valve seats (see 2.7.11) and piston-rod surfaces (see 2.8.4.1). Other exceptions are valve plates and springs where greater hardness has proven necessary. Agreement shall be reached by the manufacturer and the purchaser on alternative alloys or special heat treatment as required.

2.14.1.11 Where mating parts (such as studs and nuts) of AISI Standard Type 300 stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification and compatible with the specified gas.

Note: Torque loading values (for the same bolt stress) will be considerably different with and without the antiseizure compound.

2.14.1.12 ASTM A 515 steel can be notch sensitive and prone to brittle fracture at ambient temperatures. The use of ASTM A 515 steel is, therefore, prohibited.

2.14.1.13 O-rings shall be compatible with all specified services. For high-pressure services, special consideration shall be given to the selection of o-rings to ensure that they will not be damaged on rapid depressuring of the compressor.

CAUTION: Susceptibility to explosive decompression is dependent on the gas to which the o-ring is exposed, the compounding of the elastomer, the temperature of exposure, the rate of depressurization, and the number of cycles.

2.14.2 PRESSURE-CONTAINING PARTS

2.14.2.1 Unless otherwise specified, materials for pressure-containing cylinder parts shall be limited to the maximum gauge pressures specified in Table 2. All material selections shall be reviewed by the purchaser.

2.14.2.2 Steel compressor cylinders shall be equipped with steel heads.

2.14.2.3 The use of fabricated cylinders requires the purchaser's written approval.

2.14.2.4 Materials and the quality of all 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.

2.14.2.5 The vendor shall specify the material grade of those pressure-containing parts shown on the data sheets.

2.14.3 CASTINGS

2.14.3.1 Castings shall be sound and free of shrink holes, blow holes, cracks, scale, blisters, and other similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shotblasting, pickling, or any other standard method. All mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

Table 2—Maximum Gauge Pressures for Cylinder Materials

	Maximum Setting of Cylinder Relief Valves	
Material	Bar	Pounds per Square Inch
Gray cast iron	70	1000
Nodular iron[a]	70	1000
Cast steel	180	2500
Forged steel	No limit	No limit
Fabricated steel[b]	85	1200

[a]In the gauge pressure range 70-100 bar (1000-1500 pounds per square inch) maximum relief valve setting, nodular iron cylinders may be quoted as a separate option.
[b]See 2.14.5.1. Higher design pressures are permitted upon mutual agreement of the vendor and purchaser when based on a detailed engineering analysis.

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

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

2.14.3.4 Unless otherwise specified, the reference standards for pressure-containing castings shall be ASTM A 278 for gray iron and ASTM A 216 for steel.

2.14.3.5 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 2.14.3.5.1 through 2.14.3.5.4.

2.14.3.5.1 A minimum of one set (three samples) of Charpy V-notch impact specimens shall be made from material adjacent to the tensile specimen on each keel or Y block. These specimens shall have a minimum impact value of 12 joules (9 foot-pounds) and an average impact value of 13.5 joules (10 foot-pounds) at room temperature.

2.14.3.5.2 The tensile and keel block cast at the end of the pour shall have a minimum thickness equal to that of the thickest critical section of the main casting. These test blocks shall be tested for tensile strength and hardness and shall be microscopically examined. Classification of graphite nodules shall be in accordance with ASTM A 247.

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

2.14.3.5.4 To verify the uniformity of the casting, Brinell hardness readings shall be made on the actual castings at section changes, flanges, and other accessible locations such as the cylinder bore and valve ports. 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 sections poured first and last. These readings shall be made in addition to Brinell readings on the keel and Y blocks.

2.14.4 FORGINGS

The minimum quality standard allowed for forgings for pressure-containing parts shall be ASTM A 668.

2.14.5 FABRICATED CYLINDERS AND CYLINDER HEADS

2.14.5.1 All fabricated cylinders shall be designed based on an infinite fatigue life. The vendor shall conduct an engineering analysis that addresses the applicable loads, materials, weldments, and the geometry of the cylinder. The analysis shall ensure that the alternating stresses are limited to values that preclude the propagation of an existing internal defect.

2.14.5.2 Gas pressure-containing parts of cylinders and cylinder heads made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 2.14.5.2.1 through 2.14.5.2.8.

2.14.5.2.1 Plate subjected to alternating pressure loads used in cylinders and cylinder heads shall be subjected to the procedures in 2.14.5.2.1.1 through 2.14.5.2.1.3 after being cut to shape and before weld joint preparation.

2.14.5.2.1.1 If the plate is loaded in tension in the through-thickness direction, the surface shall be 100-percent ultrasonically inspected in the area one plate-thickness on each side of the load-imposing member (see Figure 1).

2.14.5.2.1.2 If the plate is loaded in bending, the surface shall be 100-percent ultrasonically inspected in the area one plate-thickness on each side of the load-imposing member (see Figure 2).

2.14.5.2.1.3 If the plate is axially loaded, ultrasonic inspection is not required (see Figure 3).

Note: These procedures are intended to discover laminations or inclusions that would affect the load-carrying ability of the components.

2.14.5.2.2 After preparation for welding, plate edges shall be inspected by magnetic particle or liquid penetrant examination in accordance with Section VIII, Division 1, UG-93(d)(3), of the ASME Code.

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

● **2.14.5.2.4** When specified, the quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the purchaser and the vendor before fabrication.

2.14.5.2.5 Pressure-containing welds, including welds to horizontal- and vertical-joint flanges, shall be full-penetration (complete-joint) welds unless otherwise approved by the purchaser before any fabrication.

2.14.5.2.6 All fabricated cylinders and cylinder heads shall be postweld heat treated, in accordance with Section VIII, Division 1, of the ASME Code.

Both the thickness of the welds and the section thickness of the component attachments shall be considered in the selection of heat treatment procedures. See 2.14.7.6.

2.14.5.2.7 All butt welds on the inner barrel of welded cylinders shall be 100-percent examined radiographically.

● **2.14.5.2.8** When specified, proposed cylinder, cylinder-head, and connection designs shall be made available for review and approval by the purchaser before fabrication. The drawings shall show weld designs, size, materials, and preweld and postweld heat treatments.

2.14.6 REPAIRS TO CASTINGS AND FORGINGS

● **2.14.6.1** Repairs to pressure-containing parts; moving parts subject to load reversals; and crankshafts shall not be

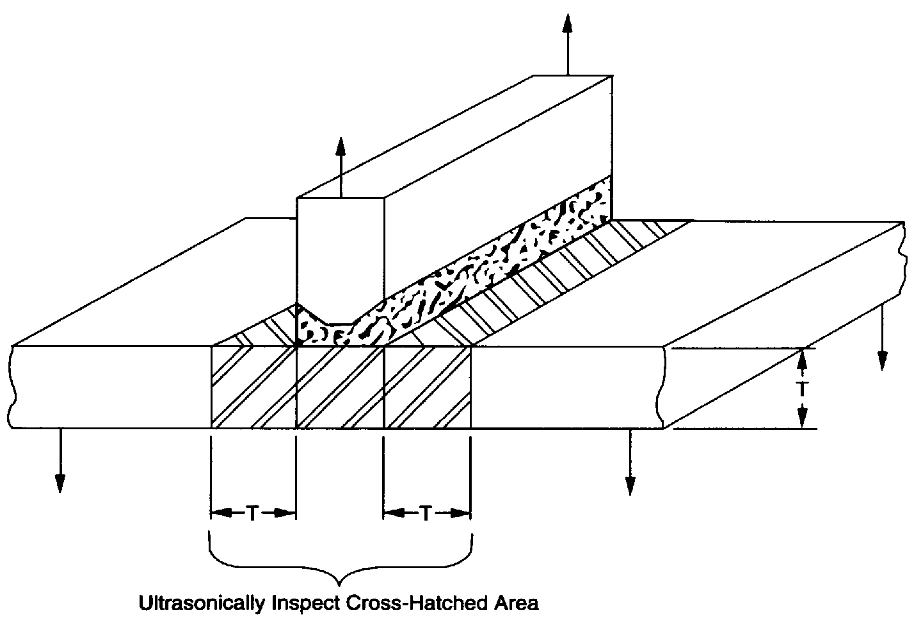

Figure 1—Plate Loaded in Tension in the Through-Thickness Direction and its Area Requiring Ultrasonic Inspection

undertaken without the written authorization of the purchaser. This could include but not be limited to the following: cylinder parts, piston and rod assembly components, and crosshead assembly components.

Before performing repairs to pressure-containing parts, the vendor shall submit sketches showing the defective area, the proposed method of repair, the materials to be used, the welding procedure, and an approval request. All such repairs shall be properly documented for the purchaser's permanent record.

For non-pressure-containing components, the vendor will make repairs in accordance with his internal quality procedures. These procedures shall be available for review by the purchaser at the manufacturer's plant.

When repairs of non-pressure-containing components are done, they must be documented by the vendor. No repair is to be made without written approval of the vendor's engineering, quality-control, and manufacturing departments.

When specified, the purchaser shall be given notice of repairs to other major components.

2.14.6.2 Pressure-containing castings shall not be repaired by peening, burning-in, or impregnating. Pressure-containing castings and forgings shall not be repaired by welding, plating, or plugging except as specified in 2.14.6.2.1 through 2.14.6.2.2.

2.14.6.2.1 Weldable grades of steel castings and forgings 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. After major weld repairs and before hydrotest, the complete casting or forging shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metals.

2.14.6.2.2 Cast gray iron or nodular iron may be repaired by plugging within the limits specified in ASTM A 278 or A 395; but they shall not be repaired by welding.

However, unless otherwise agreed on by the purchaser and the manufacturer, plugs shall not be used in the gas-pressure-containing wall sections: in particular, plugs shall not be used in the bore under the liner.

The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

Note: Appendix D briefly describes some repair techniques that may be considered for application to gray or nodular iron castings for compressor cylinders. These techniques should only be applied after a thorough mutual evaluation of the circumstances by the purchaser and the vendor.

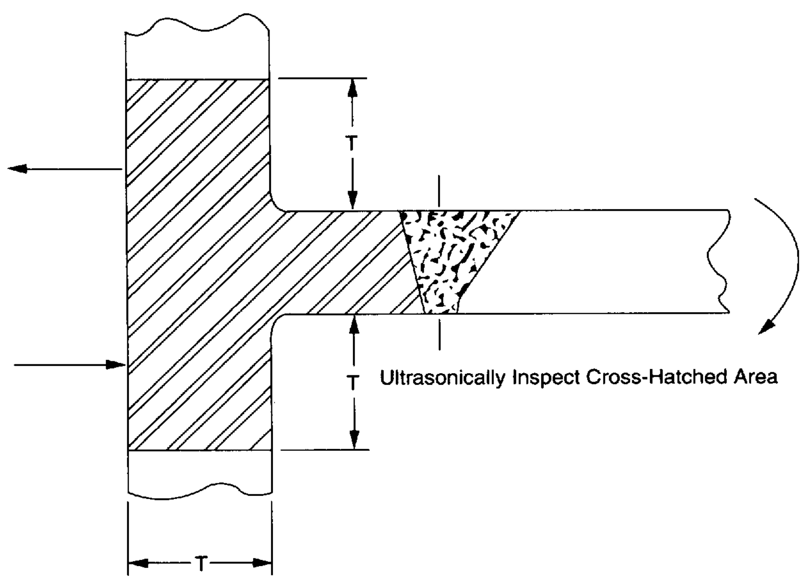

Figure 2—Plate Loaded in Bending and its Area Requiring Ultrasonic Inspection

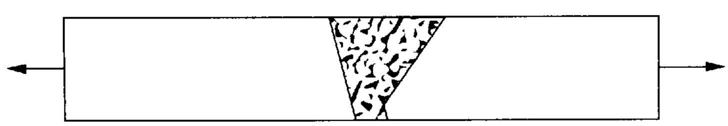

Figure 3—Axially Loaded Plate, Which Does Not Require Ultrasonic Inspection

2.14.7 WELDING

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

2.14.7.2 The vendor shall be responsible for establishing weld repair procedures that are in compliance with the applicable requirements of the ASME Code and for the implementation of repairs in accordance with these procedures, including post-repair heat treatment, if required, and nondestructive examination of repairs. Such procedures are subject to review by the purchaser before any repair is made.

2.14.7.3 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 baseplates, nonpressure ducting, lagging, and control panels, shall be performed by welders qualified in accordance with AWS D1.1 or Section IX of the ASME Code.

2.14.7.4 Inspection of repair welds shall be performed in accordance with the method used in detection of the original defect.

2.14.7.5 Connections welded to pressure-containing parts shall be installed as specified in 2.14.7.5.1 through 2.14.7.5.3.

● **2.14.7.5.1** In addition to the requirements of 2.14.7.1, the purchaser may specify that 100-percent radiography of butt welds, magnetic particle inspection of welds, or liquid penetrant inspection of welds is required.

2.14.7.5.2 When heat treating is required, piping welds shall be made before the component is heat treated.

● **2.14.7.5.3** When specified, proposed connection sketches shall be submitted to the purchaser for review before fabrication. The sketches shall show weld designs, size, materials, and pre-weld and postweld heat treatments.

2.14.7.6 When required by applicable code or paragraph 2.14.5.2.6, all welds shall be heat treated in accordance with the methods described in Section VIII, Division 1, UW-40, of the ASME Code. For steels in H_2S service, heat treatment shall also be in accordance with NACE MR0175. See 2.14.1.10.

2.14.7.7 Flux-core welding may be used for equipment in hydrogen service, on written agreement of the purchaser after submission of weld procedures.

2.14.8 LOW TEMPERATURE

The purchaser shall specify the minimum design metal temperature (MDMT) on the data sheet. Impact testing shall be in accordance with the requirements of Section VIII of the ASME Code. For materials and thicknesses not covered by the code, the purchaser will specify the requirements on the data sheets.

Note: To avoid brittle failure during operation, maintenance, transportation, erection, and testing, good design practices should be followed in the selection of fabrication methods, welding procedures, and materials for vendor-furnished carbon steel piping, fabrications, and appurtenances that may be subject to temperatures below the ductile-brittle transition point.

2.15 Nameplates and Rotation Arrows

2.15.1 A nameplate shall be securely attached at an easily accessible point on the compressor frame, on each compressor cylinder, and on any other major piece of auxiliary equipment.

2.15.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment in a readily visible location. Nameplates and rotation arrows (if attached) shall be of AISI Standard Type 300 stainless steel or of nickel-copper alloy (UNS N04400 [Monel or its equivalent]). Attachment pins shall be of the same material. Welding is not permitted.

2.15.3 The purchaser's item or tag number, the vendor's name, the machine's serial number, the compressor frame size and type, the stroke, and the rated speed shall appear on frame nameplates.

2.15.4 Nameplates on compressor cylinders shall include the rated pressure, the serial number, the bore, the stroke, the MAWP, the maximum allowable temperature, the hydrostatic test pressure, the volumetric clearance of each end (as a percent of the displacement of that end), and the cold clearance setting for each end.

2.15.5 Induction motors used for driving reciprocating compressors shall be provided with an auxiliary nameplate stating the expected full-load amperes at the expected current pulsation level based on the flywheel selection and resulting final inertia of the rotating system.

Note: The standard motor nameplate amperes are normally based on steady-state loads and may not be valid for the variable torque loads imposed by reciprocating compressors. See note in 3.1.2.6.

2.15.6 The purchaser will specify on the data sheets whether customary or SI units are to be shown on nameplates.

SECTION 3—ACCESSORIES

3.1 Drivers

3.1.1 GENERAL

● **3.1.1.1** The type of driver will be specified. The driver and power transmission equipment shall be furnished by the compressor vendor unless otherwise specified. The driver shall be sized to meet the maximum specified operating conditions, including gear and/or coupling losses, and shall be in accordance with applicable specifications as stated in the inquiry and order. All driver units shall be suitable for satisfactory operation under the specified utility and site conditions.

● **3.1.1.2** Anticipated process variations that may affect the sizing of the driver [such as (a) changes in the pressure, temperature, or properties of the fluid handled and (b) special plant start-up conditions] will be specified.

● **3.1.1.3** The starting conditions for the driver will be specified, and the starting method shall be agreed on by the purchaser and the vendor. The driver's starting-torque capabilities shall exceed the speed-torque requirements of the driven equipment.

3.1.1.4 The inertias of the rotating parts of the compressor and the drive train shall be such that rotational oscillations will be minimized. Objectionable oscillations include both those that cause damage, undue wear of parts, or interference with the governor or governing system of the driver and those that result in harmful torsional and/or electrical system disturbances. For other than motor drivers, speed oscillations of the rotating system shall be limited to $1^{1}/_{2}$ percent of rated speed at full loading and partial cylinder loadings if step unloading is specified. The compressor vendor shall inform the driver manufacturer of the nature of the application, including vibratory-torque characteristics, and shall obtain concurrence from the driver manufacturer that the driver is suitable for this service.

3.1.1.5 For purposes of sizing flywheels and couplings for gear drives, the peak-to-peak vibratory torque shall not exceed 25 percent of the torque corresponding to the maximum compressor load, and in no case shall there be any torque reversal in the gear mesh.

3.1.1.6 For a V-belt-driven compressor, the total speed variation shall not exceed 3 percent of the rated compressor speed at any operating condition (see 3.4).

3.1.2 MOTOR DRIVERS

3.1.2.1 Unless otherwise specified, motor drivers shall conform to either API Standard 541, Part 2, or API Standard 546.

3.1.2.2 For motor-driven units, the motor nameplate rating (exclusive of service factor) shall be a minimum of 110 percent of the greatest power required (including gear and coupling losses) for any of the specified operating conditions.

● **3.1.2.3** The purchaser will specify the type of motor driver, electrical characteristics, starting conditions (including expected voltage drop on starting), type of enclosure, sound pressure level, area classification based on API Recommended Practice 500, type of insulation, service factor required, ambient temperature and elevation above sea level, transmission losses, temperature detectors, vibration sensors, space heaters (if required), and auxiliaries such as motor-generator sets, ventilation blower, and instrumentation. Refer to 3.4.3 when belt drives are to be used.

● **3.1.2.4** The system'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 on by the purchaser and the vendor. The motor starting-torque shall be sufficient for starting the compressor without depressuring any stage from its normal suction pressure as long as all cylinder ends are unloaded or all stages are 100-percent bypassed. Special consideration shall be given, where applicable, to low ratios of piston-to-rod diameters, high suction pressure, high settling-out gas pressure specified by the purchaser, and high-pressure unloaded starts when compressor valve flow areas are low.

Note: Settling-out pressure is defined as the pressure of the compressor system when the compressor is shut down *without depressurization of the system.*

3.1.2.5 The design of the motor shall conform to NFPA 70 and NEMA MG 1.

3.1.2.6 The inertia of the rotating parts of the combined synchronous-motor-compressor installation shall be sufficient to limit motor current variations to a value not exceeding 66 percent of the full-load current (see NEMA MG1) for all specified loading conditions, including unloaded operation with cylinders pressurized to their normal suction pressures. For induction-motor-compressor installations, motor current variations shall not exceed 40 percent of the full-load current using the method described in NEMA MG1. The purchaser will furnish the vendor with the electrical system data necessary for proper design.

Note: The power supply for some installations may require tighter control of current variations to protect other equipment in the electrical system. Standard motor performance data are based on steady-state load conditions and may not reflect actual performance under the variable-torque conditions encountered when driving reciprocating compressors. With induction-motor drivers, the effects of variable torque and resultant current pulsations are more pronounced and require closer evaluation. See 2.15.5.

For this reason, high-efficiency induction motors with their lower slip factors may experience higher current pulsations and consequently draw higher average current and higher power than standard efficiency motors when driving reciprocating compressors.

High-efficiency induction motors are more suited to driving steady-state loads such as fans and blowers.

3.1.2.7 When the motor is supplied by the purchaser, the compressor vendor shall furnish the purchaser with the following:

a. The required motor rotor inertia (WK^2) to satisfy the flywheel requirements of the compressor for all specified operating conditions.
b. Starting-torque requirements.
c. Mounting and/or coupling details.

3.1.2.8 The rotor of a synchronous motor driver shall be mounted on a shaft extension with a keyed interference fit. The shaft extension shall be rigidly coupled to the crankshaft. The interference fit shall carry the maximum transmitted torque by itself; the key shall not be relied on to carry any of the torque. Side clearance for the key shall be 0.025 millimeter (0.001 inch) at maximum. Top clearance for the key shall be adequate to prevent overstressing of the keyway. Keyless interference fits are acceptable only if approved by the purchaser. Split or clamped hubs are not allowed. Keys and keyways shall be machined with smooth, generous radii to minimize the effects of stress concentration. An outboard bearing shall be provided by the vendor to support the end of the shaft extension on all engine-type induction motors. An outboard bearing shall be provided for engine-type synchronous motors.

3.1.2.9 For synchronous motor driven compressors, the torsional stiffness and inertia of all rotating parts shall provide at least a 20-percent difference between the inherent impulse frequency of the compressor and the natural torsional exciting frequencies of the motor (see NEMA MG1). Where the synchronous motor is to be connected to an electrical bus system that feeds existing synchronous motors, the purchaser will perform an electrical system analysis and supply the compressor vendor (and the motor vendor if the motor is separately purchased) with all data necessary to permit proper design. Unless otherwise specified, the purchaser will supply the necessary motor starting apparatus.

3.1.2.10 Cantilevered synchronous motor shafts must be approved by the purchaser and shall have sufficient rigidity to prevent the main rotor and rotating exciter from contacting their stators as a result of either shaft deflection and unbalanced magnetic forces, or dynamic mechanical unbalanced forces.

3.1.2.11 The motor manufacturer's drawing shall show the allowable tolerance for setting the air gap. All sections of the motor (and rotary exciter) stator shall be doweled after internal alignment is completed to ensure maintenance of the proper air gap. The exciter housing shall be mounted with sufficient lateral and axial rigidity to prevent excessive motion of the stator relative to the rotor.

● **3.1.2.12** The motor outboard bearing and pedestal, when provided, shall be designed to facilitate the inspection and maintenance of the bearing without resting the rotor on the stator or removing the pedestal. The rotor shall be designed so that the entire bearing and pedestal can be removed with the rotor blocked or suspended and not touching the stator. The vendor shall provide specific instructions regarding these procedures. The pedestal shall be provided with properly designed shaft seals and weather protection to keep dirt and moisture out of the lube oil. When specified, an NPS 1/4 drilled, tapped, and plugged hole shall be provided for connection of a dry air purge. The pedestal shall be provided with electrical insulation and shall have provisions for shims for adjusting alignment. The bearing shall be of the sleeve type with lubrication provided by an oil ring and sump. If specified, the bearing shall use circulated oil from the compressor frame system. The preferred method is to have the inlet oil directed onto the shaft at the oil ring location with the ring oil level maintained by a standpipe or weir in the bearing housing. Antifriction bearings may be provided if approved by the purchaser.

● **3.1.2.13** When specified, motors for auxiliary equipment shall be explosion-proof and in accordance with Article 500 of NFPA 70. The motor nameplate rating (exclusive of service factor) shall be a minimum of 110 percent of the maximum horsepower required for any operating condition.

3.1.3 TURBINE DRIVERS

● **3.1.3.1** Turbine drivers shall conform to API Standards 611, 612, or 616 as specified by the purchaser. Unless otherwise specified, turbine drivers shall be rated to deliver continuously at least 120 percent of the maximum rated compressor power plus any gear losses.

Note: The 120-percent factor includes an allowance for the cyclic torque load of reciprocating compressors.

● **3.1.3.2** When specified, a separate lube-oil system in accordance with API Standard 614 shall be furnished for a turbine drive train.

3.2 Couplings and Guards

3.2.1 COUPLINGS

3.2.1.1 When a flexible coupling between the driver and the driven equipment is required, it shall be supplied by the manufacturer of the driven equipment unless otherwise specified.

● **3.2.1.2** When specified, couplings and coupling mountings shall conform to API Standard 671. The coupling make, type, and mounting arrangement shall be agreed on by the purchaser and the vendors of the driver and driven equipment. A spacer coupling shall be used when specified.

3.2.1.3 For compressors rated at 1500 kilowatts (2000 horsepower) or more and driven by a double-reduction gear, the low-speed coupling may be a quill shaft. In such cases, the quill shaft shall be directly coupled to the compressor flywheel, shall pass through the hollow low-speed gear shaft, and shall couple with the low-speed shaft on the side opposite the compressor.

Note: Stresses in the quill shaft must be carefully considered. Typically the mean torsional stress is approximately 15 percent of the yield strength of the material. The alternating stress is typically held to a value no greater than one third of the mean torsional stress.

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

3.2.1.5 The coupling-to-shaft juncture shall be designed and manufactured to be capable of transmitting power at least equal to the power rating of the coupling.

3.2.2 GUARDS

3.2.2.1 The following shall be observed:

CAUTION: Guards shall be provided for all moving parts that might be hazardous to personnel. Guard distance to stationary housings shall be 13 millimeters (1/2 inch) or less. Openings shall be provided in flywheel guards for barring-over the machine and shall provide access to indicator timing marks, wheel center (if available), and any other parts that may require attention. Guards shall comply with specified applicable safety codes and API Standard 671, Appendix E.

Unless otherwise specified, guards shall be supplied by the vendor. They shall be easily removable, weatherproof, nonsparking aluminum with continuous welding and shall be sufficiently rigid to withstand deflection and prevent rubbing due to bodily contact. This paragraph applies to couplings on auxiliary consoles as well.

3.2.2.2 For outdoor installations, guards over V-belts and chain drives shall be weatherproofed and properly ventilated to prevent excessive heat buildup. A weatherproof access door (or doors) shall be provided as necessary to allow inspection and on-stream servicing of belts and chains.

3.3 Reduction Gears

● **3.3.1** Separate gear units shall comply with API Standard 613 or 677, as specified.

3.3.2 Gears lubricated by an integral pump shall be provided with an electrically driven standby pump arranged for automatic start-up. The system shall be arranged to prevent starting unless oil pressure has reached the minimum permissible level.

3.4 Belt Drives

3.4.1 Belt drives shall be limited to compressor applications with nominal requirements of 150 kilowatts (200 horsepower) or less and shall be banded multi-V-belts unless otherwise specified. If more than one banded multi-V-belt is required, the vendor shall furnish matched belt lengths. All belt drives shall be oil resistant (with a core of Neoprene or equivalent material) and shall be of the static-conducting type. The drive system shall be based on a service factor of 1.75 times the drive nameplate power ratings.

See 3.2.2 for belt drive guards. The details of belt tension, center distance, belt wrap, and crankshaft web deflection and testing shall be agreed on by the vendor and the purchaser.

3.4.2 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. All bearing lubrication points shall be piped to an accessible point. Piping and bearings shall be connected by flexible, heavy-duty, braided grease hose.

3.4.3 The compressor manufacturer shall inform the driver manufacturer whenever the driver is to be used to belt-drive the compressor. The drive manufacturer shall be provided with and shall take into account the radial load and vibratory-torque conditions associated with reciprocating compressors and shall provide bearings with a life at least equivalent to that specified in 2.9.3.

3.4.4 Belt drives shall meet the requirements of 3.4.4.1 through 3.4.4.4.

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

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

3.4.4.3 The compressor sheave shall be mounted on a tapered adapter bushing and fitted with a key per 3.4.4.2.

3.4.4.4 To reduce bearing moment loading (belt tension), the sheave overhang distance for the sheave-to-shaft fitting shall be minimized.

3.5 Mounting Plates

3.5.1 GENERAL

● **3.5.1.1** The equipment shall be furnished with a baseplate, a skid, soleplates, or rails as specified.

3.5.1.2 In 3.5.1.2.1 through 3.5.1.2.16, the term *mounting plates* refers to baseplates, skids, soleplates, and rails.

Note: Refer to Appendix L for typical mounting plate and soleplate arrangements.

3.5.1.2.1 The upper and lower surfaces of driver bearing pedestals shall be machined parallel.

3.5.1.2.2 The upper surfaces of mounting plates shall be machined flat and parallel to all other mounting surfaces within 0.15 millimeter per meter (0.002 inch per foot).

3.5.1.2.3 The compressor parts (such as a crankcase or a crosshead frame) shall be equipped with vertical jackscrews.

3.5.1.2.4 The feet of the drive equipment shall be equipped with vertical jackscrews.

3.5.1.2.5 When the drive equipment supported weighs more than 450 kilograms (1000 pounds), the mounting plates shall be furnished with horizontal jackscrews that are the same size as or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates so that they do not interfere with the installation or removal of the drive equipment and shims.

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

3.5.1.2.7 Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates shall be supplied with leveling screws. Mounting plates that are to be grouted shall have 50-millimeter-radiused (2-inch-radiused) outside corners (in the plan view).

3.5.1.2.8 Mounting plates shall extend at least 25 millimeters (1 inch) beyond the outer three sides of equipment feet.

3.5.1.2.9 The vendor of the mounting plates shall furnish stainless steel shim packs with a total thickness of a least 4 millimeters (1/8 inch) between the drive equipment feet and mounting plates. All shim packs shall straddle the hold-down bolts.

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

● **3.5.1.2.11** When specified, chock blocks (see Appendix L) shall be supplied by the vendor.

3.5.1.2.12 Anchor bolts will be furnished by the purchaser.

3.5.1.2.13 The drive equipment feet shall be drilled with pilot holes that are accessible for use in final doweling.

3.5.1.2.14 Mounting surfaces that are not to be grouted shall be coated with a rust preventive immediately after machining.

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

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.

● **3.5.1.2.16** When leveling plates are specified, they shall be steel plates at least 19 millimeters (¾ inch) thick. They shall be circular in shape when viewed from the top.

3.5.2 BASEPLATES AND SKIDS

3.5.2.1 Baseplates are steel members that are welded together to form equipment supports.

3.5.2.2 Skids are baseplates that have sled-type runners for ease of relocation.

● **3.5.2.3** When a baseplate is specified, the purchaser will indicate the major equipment to be mounted on it. A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor mutually agree that it may be fabricated in multiple sections. Multiple-section baseplates shall have machined and doweled mating surfaces to ensure accurate field reassembly.

Note: A baseplate with a nominal length of more than 12 meters (40 feet) or a nominal width of more than 4 meters (12 feet) may have to be fabricated in multiple sections because of shipping restrictions.

3.5.2.4 Baseplates shall be of welded construction. Abutting beams shall be welded on both sides. Splicing flanges of load-bearing members is not acceptable. Contact between webs at perpendicular joints shall be a minimum of one third of the depth of the smallest member.

3.5.2.5 The compressor crankcase, crosshead frame, cylinder supports, and drive equipment shall be supported on full-depth, load-bearing structural members.

3.5.2.6 Holes shall be provided for anchor bolts on internal and external load-bearing structural members to assure that forces and moments are properly transmitted to the foundation.

3.5.2.7 Baseplates shall be designed and built to adequately support the weight of the compressor, driver, and accessories. The baseplate shall be able to transmit all forces and moments generated by the compressor and driver to the foundation.

Note: The compressor and driver system should be reviewed to ensure that the baseplate is designed to avoid being in resonance with the operating-speed frequency or any multiple thereof.

3.5.2.8 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 the machinery mounted on it.

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

3.5.2.10 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members. The members shall be shaped to lock positively into the grout.

3.5.2.11 The mounting pads on the bottom of each baseplate shall be in one plane to permit use of a single-level foundation.

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

3.5.2.13 Supports, braces, and auxiliary equipment shall be mounted on load-bearing structural members.

3.5.2.14 Driver and compressor baseplate mounting pads shall be machined after the baseplate is fabricated. See 3.5.1.2.2.

3.5.3 SOLEPLATES AND RAILS

3.5.3.1 Soleplates (see Appendix L) are grouted plates installed under motors, bearing pedestals, gearboxes, turbine feet, cylinder supports, crosshead pedestals, and compressor frames.

3.5.3.2 Rails are soleplates extending the full length of each side of the equipment. They may be composed of multiple segments.

● **3.5.3.3** When soleplates or rails are specified, they shall be provided by the vendor.

3.5.3.4 Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, but in no case shall they be less than 40-millimeters (1 1/2-inches) thick.

3.6 Controls and Instrumentation

3.6.1 GENERAL

● **3.6.1.1** Compressor control systems may be pneumatic, hydraulic, electrical, or electronic, and they may be operated either manually or automatically. The purchaser will specify the control signal, the type of control system (manual, automatic, or programmable), the control range, and the equipment to be furnished by the vendor. The purchaser will specify which process-sensing lines handling flammable, toxic, corrosive, or high-temperature fluids require transduced signals to the instrumentation. The purchaser will also specify the source of the control signal and its sensitivity and range. Refer to Appendix E for specific types of logic diagrams and controls.

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

3.6.1.3 Where applicable, controls and instrumentation shall conform to API Recommended Practice 550, Part I.

3.6.1.4 All controls and instruments shall be located and arranged for ease of visibility, access, and maintenance.

3.6.1.5 All instrumentation furnished by the compressor manufacturer requires the purchaser's review. Freestanding panels are preferred. All instrumentation shall be securely supported to eliminate vibration and undue force on instrument piping and to prevent damage during shipping, storage, operation, and maintenance.

3.6.1.6 Some controls may be shipped loose for field installation in the purchaser's piping. Purchaser and vendor shall have prior agreement on the exact scope of supply for these loose items. Refer to 4.4.3.11 for shipment.

● **3.6.1.7** Unless otherwise specified, all instruments and controls other than shutdown-sensing devices shall be installed with sufficient valving to permit 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.

3.6.1.8 All tubing connections that must be dismantled for shipment shall have matched tags (at initiation point, intermediate sections, and application point) attached by stainless steel wire.

3.6.2 CONTROL SYSTEMS

● **3.6.2.1** When variable-speed drive is specified, the speed of the drive shall vary linearly with the control signal, and an increase in signal will increase driver speed. Unless otherwise specified, the full range of the purchaser's signal shall correspond to the required operating range of the compressor for all specified operating conditions.

Note: Reciprocating compressors are usually specified for constant-speed operation (see 2.1.4).

● **3.6.2.2** The unloading arrangement for start-up and shutdown shall be stated on the data sheets and shall be agreed on by the purchaser and the vendor. When specified, an automatic loading-delay interlock shall be provided to prevent automatic loading during start-up. When specified, automatic immediate unloading shall be supplied to permit re-acceleration of the motor after a temporary electric power failure of a agreed-on maximum duration. The vendor and the purchaser shall agree on the modes and duration of unloaded and partially loaded compressor operation. The vendor shall be responsible for the loading-unloading sequence.

3.6.2.3 Capacity control for constant-speed units normally will be obtained by suction valve unloading, clearance pockets, a combination of both pockets and unloaders, or bypass (internal-plug type or external). Control operation shall be either automatic or manual as specified on the data sheets. Unless otherwise specified, five-step unloading shall provide nominal capacities of 100, 75, 50, 25, and 0 percent; three-step unloading shall provide nominal capacities of 100, 50, and 0 percent; and two-step unloading shall provide capacities of 100 and 0 percent.

3.6.2.4 Capacity control on variable-speed units is usually accomplished by speed control, but capacity control can be supplemented by the control methods listed in 3.6.2.3.

● **3.6.2.5** Clearance pockets may be of either the fixed type (with pocket either open or closed) or the variable type. If a choice is not specified by the purchaser, the vendor shall recommend the type of clearance pockets to be used for the purchaser's operating conditions. Each added clearance volume shall be included in the data sheets to indicate the clearance it adds to the cylinder.

3.6.2.6 When a machine-mounted capacity control is specified, the vendor shall provide a panel complete with (a) a positive-detent-type master selector valve (one for each service on multiservice compressors) to obtain the specified load steps and (b) indicators to show at which step the machine is operating.

3.6.3 INSTRUMENT AND CONTROL PANELS

● **3.6.3.1** When specified, a panel shall be provided and shall include all panel-mounted instruments for the compressor and the driver. Such a panel shall be designed and fabricated in accordance with the purchaser's description. The instruments on the panel shall be clearly visible to the operator from the driver control point. A lamp-test push button shall be supplied.

● **3.6.3.2** Unless otherwise specified, panels shall be at least 3-millimeter (12-gauge) steel plate that is reinforced, self-supporting, and closed on the top and sides.

CAUTION: When specified, the backs of panels shall be enclosed to minimize electrical hazards, to protect equipment against tampering, or to allow purging for safety or corrosion prevention.

All instruments shall be flush-mounted on the front of the panel, and all fasteners shall be of corrosion-resistant material.

3.6.3.3 Panels shall be completely assembled and shall require 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. The box shall be mounted on the unit (or its base, if any). Wiring shall be installed in metal conduits or enclosures. All instruments, leads and posts on terminal strips, and switches shall be affixed with permanent tags for identification. All instrument and switch tags shall be stainless steel and attached with stainless steel wire. All instrument lead tags shall be of the plastic sleeve heat-shrink type.

3.6.3.4 Interconnecting shop-fabricated piping, tubing, and wiring for controls and instrumentation when furnished and installed by the vendor shall be disassembled only as necessary for shipment.

3.6.4 INSTRUMENTATION

● **3.6.4.1 Tachometers**

A tachometer shall be provided when specified. The type, range, and indicator provisions shall be stated by the purchaser. When a turbine driver is to be used, the turbine vendor shall furnish the speed sensor and indicator(s).

3.6.4.2 Temperature Measurement

● **3.6.4.2.1** Temperature indicators shall be furnished and mounted locally or on a panel, as specified.

3.6.4.2.2 Dial-type temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 125 millimeters (5 inches) in diameter and bimetallic or liquid filled. Black printing on a white background is standard for gauges. Metal-case, glass-front, stem-type liquid-filled thermometers shall be furnished in locations subject to vibration.

3.6.4.2.3 The sensing elements of thermometers and temperature gauges shall be in the flowing fluid. This is particularly important for lines that may run partially full.

3.6.4.2.4 Thermometers and temperature gauges that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with AISI Standard Type 300 stainless steel separable-flange-type solid-bar thermowells that are at least 19 millimeters ($^3/_4$ inch) in diameter.

3.6.4.2.5 Heat-transfer compound shall be used between thermowells and sensing elements.

● **3.6.4.2.6** Packing temperature indication (by thermocouple or resistance temperature detector [RTD] as specified) shall be provided for cylinders operating at or above a gauge pressure of 35 bar (500 pounds per square inch) and for all cylinders with liquid-cooled packing (see 2.11.4). Unless otherwise specified, indicators shall be mounted on an instrument board located on the compressor near the force-feed lubricator.

3.6.4.2.7 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 compressor shall be provided.

● **3.6.4.2.8** When specified, main bearing and valve temperature detectors shall be supplied. Details of all equipment furnished (such as thermocouples, resistance temperature detectors [RTDs], and intrinsically safe systems) shall be a joint effort of the purchaser and the vendor.

3.6.4.3 Pressure Measurement

● **3.6.4.3.1** Pressure indicators shall be furnished and mounted locally or on a panel, as specified.

● **3.6.4.3.2** Pressure gauges (not including built-in instrument-air gauges) shall be furnished with AISI Standard Type 316 stainless steel bourdon tubes and stainless steel movements, 100-millimeter (4 1/2-inch) dials [150-millimeter (6-inch) dials for the range over 55 bar (800 pounds per square inch)] and NPS 1/2 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 at the middle 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 disk insert or blowout back designed to relieve excess case pressure.

3.6.4.3.3 All pressure gauges shall be furnished with isolation and bleed valves.

3.6.4.4 Solenoid Valves

Direct solenoid-operated valves shall be used only in a 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 to pneumatic valves, hydraulic valves, and the like.

3.6.4.5 Relief Valves

● **3.6.4.5.1** When specified, the vendor shall furnish relief valves that are to be installed on equipment or in piping that the vendor is supplying. Other relief valves shall 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 the set pressure of all relief valves related to the equipment. The vendor's proposal 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.

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

3.6.4.5.3 Relief valves shall be set to operate at not more than the maximum allowable working pressure, but not less than the values listed in Table 3.

3.6.5 ALARMS AND SHUTDOWNS

● **3.6.5.1** Protective devices shall be furnished by the vendor or the purchaser as indicated. Table 4 lists the minimum recommended protective devices. The vendor shall furnish all other instrumentation indicated on the data sheets by the purchaser. The vendor shall recommend protective devices, in addition to those specified, which are deemed necessary to prevent damage to equipment. The trip system shall be suitable for remote actuation. For the selection and mounting location of the devices, instrumentation, and panels, consideration must be given to the degree of packaging to be done by the vendor.

Table 3—Relief Valve Settings

Rated Discharge Gauge Pressure		Minimum Relief Valve Set Pressure Margin Above Rated Discharge Gauge Pressure
Bar	Pounds per Square Inch	
≤ 10	≤ 150	15 psi (1 bar)
> 10 to 170	> 150 to 2500	10 percent
> 170 to 240	> 2500 to 3500	8 percent
> 240 to 345	> 3500 to 5000	6 percent
> 345	> 5000	([a])

[a]For rated discharge gauge pressures above 345 bar (5000 pounds per square inch), the relief valve setting shall be agreed on by the purchaser and the vendor.

Table 4—Minimum Alarm and Shutdown Requirements

Condition	Alarm	Shutdown
High gas discharge temperature for each cylinder	X	X
Low frame lube-oil pressure	X	X
Low frame lube-oil level	X	—
Cylinder lubricator system failure	X	—
High oil-filter differential pressure	X	—
High frame vibration	—	X
High level in separator	X	X
Jacket water system failure	X	—

Note: X = when the condition occurs, alarm or shutdown is required; — = when the condition occurs, alarm or shutdown is not required.

3.6.5.2 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 1/2 ampere at 120 volts DC shall be used. Mercury switches shall not be used.

3.6.5.3 Switches (except vibration switches) shall be installed so that the vibration of the equipment will not cause the switch to operate.

3.6.5.4 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 (see Figure E-1). 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.

3.6.5.5 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 valve 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.

3.6.5.6 The vendor shall furnish with the proposal a complete description of the alarm and shutdown facilities to be provided.

3.6.5.7 Alarm and shutdown switches shall be suitable for operation on both AC and DC. All parts in contact with the process fluid or lube oil shall be stainless steel. Unless otherwise agreed on, AISI Standard Type 300 Series stainless steel tubing shall be used within the confines of the panel. All alarm and shutdown devices shall function directly, not through the control panel.

•**3.6.5.8** 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 3.6.5.8.1 through 3.6.5.8.4.

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

3.6.5.8.2 The alarm condition shall be acknowledged by operating an alarm-silencing button common to all alarm functions. It shall be suitably located on the panel.

3.6.5.8.3 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.

3.6.5.8.4 If more than one device alarms, then a first-out sequence annunciating system shall be activated.

3.6.5.9 Unless otherwise specified, electric switches that open (de-energize) to alarm and close (energize) to trip shall be furnished by the vendor. Refer to Appendix E for a typical logic diagram.

• **3.6.5.10** When specified, crossheads shall be equipped with a high crosshead-pin temperature alarm to protect the crosshead-pin bushing.

Note: The system may consist of a spring-loaded eutectic device, which shall de-energize a pneumatic or hydraulic circuit on alarm.

3.6.6 ELECTRICAL SYSTEMS

3.6.6.1 All electrical components and their installation shall conform to the requirements of 2.1.7. Unless otherwise specified, all electrical devices located on the compressor or auxiliary systems shall be suitable for Class I, Group D, Division 2, area classification.

• **3.6.6.2** When panels are supplied by the vendor, electrical power supply characteristics for motors, heaters, and instrumentation shall be specified by the purchaser. 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.

3.6.6.3 Power and control wiring within the confines of the main unit base area, any console base area, or any auxiliary base area 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. Where rubber insulation is used, a Neoprene (or equivalent) or high-temperature thermoplastic sheath shall be provided for insulation protection. Wiring shall be suitable for environmental temperatures.

3.6.6.4 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.

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

● **3.6.6.6** All electric materials, including insulation, shall be as corrosion resistant and nonhygroscopic insofar as is possible. When specified for tropical location, all material shall be given the treatments specified in 3.6.6.6.1 and 3.6.6.6.2.

3.6.6.6.1 All parts (such as coils and windings) shall be protected from fungus attack.

3.6.6.6.2 Unpainted surfaces shall be protected against corrosion by plating or another suitable coating.

3.6.6.7 All wiring (including power and instrumentation leads) within limits of any base area 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 of sufficient length to permit access to the unit for maintenance without removal of the conduit. If thermocouple heads will be exposed to temperatures above 60°C (140°F), a 20-millimeter (3/4-inch) bronze hose having four-wall interlocking construction and joints with packed-on (heat-proof) couplings shall be used.

3.6.6.8 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.

3.6.7 VIBRATION AND POSITION DETECTORS

● **3.6.7.1** When specified, the vendor shall furnish and mount one or more vibration detection and transducing devices. Each device shall have a velocity or accelerometer-type detector, and each shall provide for each of the following functions: (a) continuous vibration measurement, (b) alarm, and (c) shutdown. The device and its mounting shall conform to API Standard 670. Ball-and-seat or magnetic-type switches are unacceptable. The purchaser and the vendor shall agree on the type, number, and location of the devices to be mounted on the compressor frame (and on gear units, if applicable).

● **3.6.7.2** When specified, a noncontacting proximity-type probe with oscillator-demodulator and connecting cable shall be installed and calibrated in accordance with API Standard 670 to measure the vertical runout of each piston rod. Unless otherwise specified, each probe shall be mounted on the packing gland. Terminal boxes containing oscillator-demodulators shall not be mounted on the machine. If the piston rod is coated, the proximity probe shall be calibrated on the individual coated rod itself.

● **3.6.7.3** When specified, a one-event-per-revolution machined mark on the crankshaft and corresponding phase-reference transducer(s) shall be provided to permit synchronization on top dead center (TDC) with a cylinder performance analyzer and/or rod-drop detector. Transducers shall be supplied, installed, and calibrated in accordance with API Standard 670.

● **3.6.7.4** When specified, the vendor shall furnish and mount rod-drop detectors of the contact type. The detectors shall be of the mechanical roller or fuse-metal plug (eutectic) type. Unless otherwise specified, each detector shall be mounted on the packing gland. Inert gas, instrument air, or hydraulics shall be used to pressurize the detector system. Diaphragm pressure switches (see 3.6.5.2) shall be used to sense loss of pressure.

3.7 Piping and Appurtenances

3.7.1 GENERAL

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

3.7.1.2 Auxiliary systems are defined as piping systems that are in the following services:

a. Group I Service.
   1. Purge or buffer gas.
   2. Fuel gas or oil.
   3. Distance piece and packing vents and drains.
   4. Drains and vents.

b. Group II Service.
   1. Sealing steam.
   2. Drains and vents.

c. Group III Service.
   1. Cooling water.
   2. Packing cooling systems.
   3. Instrument and control air; or inert gas.
   4. Bar-over air.
   5. Drains and vents.

d. Group IV Service.
   1. Lubricating oil.
   2. Control oil.
   3. Drains and vents.

The minimum requirements for piping materials for auxiliary systems shall be as specified by Table 5 and 3.7.1.12.

Note: Cylinder connections are discussed in 2.6.4.

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

3.7.1.4 If special flanges that are not in accordance with ANSI standards are unavoidable, the vendor shall supply a weld-neck companion flange, bolting, and a gasket to be installed by the purchaser. The purchaser shall be advised of this situation in the proposal.

Table 5—Minimum Requirements for Piping Materials

System	Group I Auxiliary Process Fluid: Nonflammable/ Nontoxic	Group I Auxiliary Process Fluid: Flammable/ Toxic	Group II Steam	Group III Cooling Water, Air ≤ 125 psig	Group IV Lubricating & Control Oil
Pipe	Seamless	Seamless	Seamless	Seamless	Stainless steel[a]
Tubing	Seamless stainless steel or steel	Seamless stainless steel or steel	Stainless steel or steel	Seamless stainless steel	Seamless stainless steel[a]
All valves	Class 800	Class 800	Class 800	Carbon steel Class 800	Carbon steel Class 800
Pipe fittings and unions	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	Carbon steel	Stainless steel[b]
Fabricated joints ≤ 1½ inches	Threaded	Socket welded threaded	Threaded	Threaded or flanged	—
Fabricated joints ≥ 2 inches	Flanged	Flanged	—	Carbon steel flanged	Flanged

Note: — = no requirement.
[a]See 3.7.2.5.
[b]See 3.7.2.4.

● **3.7.1.5** The extent of process and auxiliary piping to be supplied by the vendor shall be specified by the purchaser. When specified, piping, pulsation suppression devices, and knockout vessels at the initial and interstage suction points shall be arranged for heat tracing and insulation.

3.7.1.6 The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, any console base area, or any auxiliary base area. The purchaser will furnish only interconnecting piping between equipment groupings and off-base facilities. The following connections shall terminate with flanged connections at the edge of the base: (a) the connections for interconnecting piping between groupings, (b) the connections for air, water, steam, and other utility services to a base area, and (c) other purchaser's connections. Instrument-tubing connections shall terminate with NPS connections. Piping and component drains and vents that are NPS 1½ and smaller shall terminate with a plugged drain or vent valve accessible from the edge of the base or a work area. This is to keep work areas and walkways as free as possible from obstructions. All piping that cannot be installed and supported for shipping shall be completely fabricated, fitted, pre-assembled, preserved, match-marked and tagged, before disassembly in the vendor's shop to facilitate field assembly.

● **3.7.1.7** When specified, the vendor shall review drawings of all piping, appurtenances (pulsation suppression devices, intercoolers, aftercoolers, separators, knockouts, air intake filters, and expansion joints), and vessels immediately upstream and downstream of the equipment and supports. The purchaser and the vendor shall agree on the scope of this review.

3.7.1.8 Internals of piping and appurtenances shall be accessible through openings or by dismantling for complete visual inspection and cleaning.

3.7.1.9 Connections NPS 1½ and smaller shall be designed to minimize overhung weight and shall be braced back to the main pipe in at least two planes to avoid breakage due to pulsation-induced vibration. Bracing shall be arranged to occupy minimum space.

3.7.1.10 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. Supports shall not be directly welded to process or auxiliary piping (except bracing of small connections as allowed in 3.7.1.9).
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 obstructing access openings.
d. Elimination of air pockets in liquid systems by the use of valved vents or non-accumulating piping arrangements.

e. Complete drainage through low points without disassembly of piping.
f. Elimination of low points in the inlet process piping that could trap liquid.
g. Equipping of all compressor cylinder piping with valved coolant vents and drains. See Figure G-1.

3.7.1.11 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. Threaded connections shall be held to a minimum.

3.7.1.12 The requirements of 3.7.1.12.1 through 3.7.1.12.27 shall be applied to piping systems within the scope of this standard.

3.7.1.12.1 Pipe threads shall be taper threads in accordance with ASME B1.20.1. Alternately, pipe threads in accordance with ISO 228, Part 1 are acceptable when required for compliance with local standards. Flanges shall be in accordance with ISO 7005 (ASME B16.5) except that lap-joint and slip-on flanges shall not be used. For socket-welded construction, a 2-millimeter (1/16-inch) gap shall be left between the pipe end and the bottom of the socket.

Note: Slip-on flanges are not used on piping and appurtenances around reciprocating compressors because of their reduced fatigue life.

3.7.1.12.2 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.

3.7.1.12.3 Where space does not permit the use of NPS 1/2, 3/4, or 1 pipe, seamless tubing may be furnished in accordance with Tables 5 and 6.

3.7.1.12.4 The minimum size of any pipe connection shall be NPS 1.

Table 6—Minimum Tubing Wall Thickness

Nominal Tubing Size (OD in inches)	Minimum Wall Thickness	
	Millimeters	Inches
1/4[a]	0.89	0.035
3/8[a]	0.89	0.035
1/2	1.65	0.065
3/4	2.41	0.095
1	2.76	0.109

[a]OD Nominal Tubing Sizes (NTS) ¼ inch and ⅜ inch are permitted for instrument-air, control-air, and inert-gas purges only.

3.7.1.12.5 Steel flanges mating with iron compressor flanges shall be flat faced.

3.7.1.12.6 Pipe threads shall be coated with a nonlocking pipe thread sealant. Polytetrafluoroethylene (PTFE) pipe tape is not acceptable.

3.7.1.12.7 Welding shall be performed by operators and through procedures qualified in accordance with Section IX of the ASME Code.

3.7.1.12.8 All piping components—such as flanges, valves, control valve bodies or heads, and relief valves—shall be made of steel.

3.7.1.12.9 Threaded joints for flammable or toxic fluids or for steam gauge pressures above 5 bar (75 pounds per square inch) shall be seal welded; however, seal welding is not permitted on cast iron equipment, on instruments, or where disassembly is required for maintenance. Seal-welded joints shall be made in accordance with ASME B31.3.

3.7.1.12.10 Valves shall meet the applicable portions of API Standards 600, 602, or 606. Gate and globe valves shall have bolted bonnets and bolted glands. Valves over NPS 2 for ANSI Class 600 or lower shall be flanged. For primary ANSI service ratings Class 900 and above, block valves may be of welded bonnet or no-bonnet construction with a bolted gland; these valves shall be suitable for repacking under pressure. Wafer check valves in accordance with API Standard 594 may be used in sizes NPS 2 and larger. Butterfly valves shall not be used unless approved by the purchaser.

3.7.1.12.11 Block valves shall be supplied with nominal 13Cr stainless steel trim.

3.7.1.12.12 Instrument valves for oil and gas service located in sensing lines downstream of a primary service block valve may be bar-stock instrument valves, provided the valve is protected against accidental disassembly. Valves shall be stainless steel or carbon steel, with a corrosion-resistant plating and stainless steel stem.

3.7.1.12.13 Bleed valves provided at instruments may be the manufacturer's standard bleed fitting. Where test valves are provided per 3.7.5.3, bleed valves may be omitted.

3.7.1.12.14 Control valves shall have steel bodies, flanged ends, and stainless steel trim.

3.7.1.12.15 The bolting for pressure joints, valves, and piping shall be based on the actual bolting temperature as defined in ASME B 31.3. As a minimum, pressure bolting shall be ASTM A 193 Grade B7 with ASTM A 194 Grade 2H nuts in accordance with the requirements of ASME B1.1. Through-studs shall be used. Bolting shall be in accordance with 2.6.2.11.

3.7.1.12.16 Pipe flange gaskets shall be non-asbestos flat gaskets up to and including ANSI Class 300 pressure ratings. For ANSI Class 600 and higher ratings, spiral wound gaskets with non-asbestos filler, an external centering ring, and AISI Standard Type 304 or 316 windings shall be supplied.

3.7.1.12.17 Pipe bushings, unions, and couplings shall not be used.

3.7.1.12.18 Combination stop/check valves shall not be used.

3.7.1.12.19 Gaskets and packings for flanges, valves, and other components shall not contain asbestos.

3.7.1.12.20 Carbon steel piping shall conform to ASTM A 106, Grade B, and ASTM A 524. Stainless steel piping shall be seamless in accordance with ASTM 312, Type 304 or 316. Pipe wall thickness shall be in accordance with Table 7.

3.7.1.12.21 All tubing shall be seamless stainless steel tubing and shall conform to ASTM A 269, Type 304. Tubing wall thickness shall be in accordance with Table 6.

3.7.1.12.22 Tubing fittings shall be stainless steel and the manufacturer's standard as approved by the purchaser.

Note: Flared tubing fittings are not recommended.

3.7.1.12.23 Tubing valves shall be the manufacturer's standard tube-end or instrument valve and shall be stainless steel, as approved by the purchaser.

● **3.7.1.12.24** Special requirements for piping, flanges, valves, and other appurtenances in hydrogen, hydrogen sulfide, or toxic services will be specified by the purchaser.

3.7.1.12.25 Carbon steel pipe fittings shall conform to ASTM A 105 Class 3000, SWE or TE, or ASTM A 234, wrought butt weld. Flanges shall conform to ASTM A 105 or A 181. Stainless steel pipe fittings shall conform to ASTM A 182, Type F 304, Class 3000, SW, TE, or ASTM A 403, WP 304, wrought butt weld. Flanges shall conform to ASTM A 182, Type 304.

3.7.1.12.26 Inert gas purge systems shall be stainless steel downstream of the filters.

3.7.1.12.27 All flanges shall be socket-weld or weld-neck flanges. Lap-joint or slip-on flanges are not allowed.

Table 7—Minimum Pipe Wall Thickness

Material	Pipe Size (NPS)	Minimum Schedule
Carbon steel	$\leq 3/4$	160
Carbon steel	$1–1\,1/2$	80
Carbon steel	≥ 2	40
Stainless steel	≤ 1	80S
Stainless steel	$1\,1/2–3$	40S
Stainless steel	≥ 4	10S

3.7.1.13 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 centerlines of the equipment.

● **3.7.1.14** When specified, each utility—such as air and gas supply, cooling water supply and return lines, and others as specified by the purchaser—shall be manifolded to a common connection.

The cross-sectional area of the manifold shall equal or exceed the sum of the cross-sectional areas of the connected branches.

3.7.2 FRAME LUBRICATING OIL PIPING

3.7.2.1 The vendor shall supply a complete lubricating oil piping system (with its mounted appurtenances) if it is to be located within the confines of the main unit base area, any assembly (console) base, or any packaged unit accessory. The vendor shall provide interconnecting piping when auxiliary equipment is specified to be located immediately adjacent to the compressor in the vendor's recommended location. Refer to 2.12.2, 2.12.3, and 3.7.1.6.

3.7.2.2 Oil drains shall be sized to run at not more than half full when flowing at a velocity of 0.3 meter per second (1 foot per second) and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Horizontal runs shall slope continuously at a slope of at least 40 millimeters per meter (1/2 inch per foot) toward the reservoir. If possible, laterals (not more than one in any transverse plane) should enter drain headers at 45-degree angles in the direction of the flow.

3.7.2.3 The vendor shall specify the maximum piping distance and the required elevation difference between the main frame and any auxiliary oil console.

3.7.2.4 Nonconsumable backup rings and sleeve-type joints shall not be used. Pressure piping that is downstream of oil filters shall be free from internal obstructions that could accumulate dirt. Socket-welded fittings shall not be used in pressure piping that is downstream of oil filters (see Table 5).

3.7.2.5 Unless otherwise specified, oil piping (with the exception of cast-in-frame lines or passages) and tubing, including fittings, shall be stainless steel (see Table 5).

3.7.2.6 After fabrication, oil lines shall be thoroughly cleaned.

● **3.7.2.7** Heads of oil-actuated control valves shall be vented back to the reservoir. When specified, instrument sensing lines to safety switches shall have a continuous through-flow of oil.

3.7.3 FORCE-FEED LUBRICATOR TUBING

3.7.3.1 Oil feed lines from force-feed lubricators to cylinder and packing lubrication points shall be at least 1/4 Nominal Tubing Size (OD in inches) with a minimum wall thickness of 1.5 millimeters (0.065 inch). Tubing shall be seamless ASTM A 269 stainless steel. Fittings shall be AISI Standard Type 300 Series stainless steel. See 2.13.1.7 for check valves.

Note: For high-pressure compressors, heavier wall thickness tubing may be required.

3.7.3.2 Tubing shall be run together where possible. When winterization is specified, the tubing shall stand off from the machine to allow insulation.

3.7.4 COOLANT PIPING

3.7.4.1 If the purchaser does not specify the extent of coolant piping, the vendor shall supply piping with a single inlet connection and a single outlet connection on each cylinder requiring cooling. See Figure G-1, Plan C.

3.7.4.2 Both the coolant inlet line and the coolant outlet line to each compressor cylinder shall be provided with a gate valve. A globe valve with union shall be provided on the main outlet line from each cylinder. A sight-flow and temperature indicator shall be installed in the common coolant outlet line from each cylinder. Where more than one coolant inlet point and one coolant outlet point exist on a cylinder, one sight-flow indicator and a regulating globe valve shall be provided for each coolant outlet point on the cylinder.

● **3.7.4.3** When coolant piping on the compressor is specified to be furnished by the vendor, the vendor shall supply a piping system for all equipment mounted on the compressor or the compressor base. The piping shall be arranged to provide a single inlet connection and a single outlet connection for each water circuit operating at different inlet temperature levels and shall include a coolant control valve and a flow indicator as noted in 3.7.4.2. Series-type circuits shall have the valved bypasses necessary to provide temperature control.

3.7.4.4 Where a thermosyphon or a static cooling system is provided (see 2.6.3.1), the vendor shall furnish piping with a drain valve at its lowest point and an expansion tank (complete with fill-and-vent connections and level indication) sized to prevent overflow of coolant. See Figure G-1, Plans A and B. A thermometer is required for a thermosyphon system. For coolant connections, the purchaser's connections shall be flanged. Cylinder connections of NPS 1 1/2 and smaller may be threaded.

3.7.5 INSTRUMENT PIPING

3.7.5.1 The vendor shall supply all necessary piping, valves, and fittings for all instruments and instrument panels (see 3.6.3.3).

3.7.5.2 Connections on equipment and piping for pressure instruments and test points shall conform to 3.6.1.7. Beyond the initial NPS 3/4 isolating valve, piping that is NPS 1/2, tubing, valves, and fittings may be used. When convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Separate secondary NPS 1/2 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 the pressure gauge and switches.

● **3.7.5.3** When specified, a test valve shall be supplied adjacent to all instruments. Test valves shall terminate with a plugged NPS 1/2 connection. When specified, test valves in oil lines shall be vented back to the reservoir. Test valves may be combined with instrument valves supplied per 3.7.1.12.13.

3.7.6 PROCESS PIPING

● **3.7.6.1** The extent of and requirements for process piping to be supplied by the vendor will be specified.

3.7.6.2 The requirements of 3.7.1 shall apply to process piping supplied by the vendor.

● **3.7.6.3** When compressor process inlet piping and pulsation suppression equipment are furnished by the vendor, provisions shall be made for the insertion of temporary start-up screens just upstream of the suction pulsation suppression device. The design of the piping system, the suction pulsation suppression device, and the temporary start-up screens shall afford easy removal and reinsertion of the screens without the necessity of pipe springing. When it is specified that the screens are to be furnished by the vendor, the design, location, and orientation of the screens shall be submitted to the purchaser for approval before manufacture or purchase by the vendor. When specified, the vendor shall supply both the removable spool pieces that accommodate temporary start-up screens and sufficient NPS 1 pressure taps to allow monitoring of pressure drop across the screen.

3.7.7 DISTANCE PIECE DRAIN AND VENT PIPING

Drain and vent piping serving individual cylinders shall not be less than NPS 1 or 3/4 Nominal Tubing Size (OD in inches). Drain and vent headers shall not be less than NPS 2.

Vent connections in the packing case and interconnecting tubing within a distance piece shall be of AISI Standard Type 300 Series stainless steel and of at least 1/4 Nominal Tubing Size (OD in inches) with a minimum wall thickness of 1.24 millimeters (0.049 inch).

Refer to Appendix I for a typical distance piece vent and drain system.

3.8 Intercoolers and Aftercoolers

● **3.8.1** When specified, the vendor shall furnish a water-cooled shell-and-tube intercooler between each compression stage.

● **3.8.2** The purchaser will specify whether aftercoolers shall be furnished by the vendor.

● **3.8.3** Water-cooled shell-and-tube intercoolers and aftercoolers shall be designed and constructed in accordance with TEMA Class C or R, as specified by the purchaser. Intercoolers and aftercoolers shall be furnished in accordance with Section VIII, Division I, of the ASME Code. When TEMA Class R is specified, the heat exchanger shall be in accordance with API Standard 660.

CAUTION: Caution should be exercised regarding the susceptibility of heat exchangers and their supporting structures to pulsation-induced vibration.

3.8.4 Unless otherwise specified, the water side of shell-and-tube heat exchangers shall be designed in accordance with 2.1.3.

3.8.5 Unless otherwise approved by the purchaser, intercoolers and aftercoolers shall be constructed and arranged to allow the removal of tube bundles without the dismantling of piping or compressor components. Water shall be on the tube side.

CAUTION: Intercooling and after-cooling of gases from reciprocating compressors present some unique phenomena to be considered in the design of the exchanger. Consideration should be given to gas on the tube side if multipass exchange is desired. Very small pressure pulsation levels multiplied by the larger areas of the pass separator plates can possibly produce very high vibratory forces in the tube bundle. Consideration should also be given to the application of shell-side rupture discs, relief valves, or similar devices.

3.8.6 Fixed-tube-sheet exchangers shall have inspection openings into their gas passages. Rupture disks on the shell side (to protect the shell in case of tube failures) shall be used only when specifically approved by the purchaser.

● **3.8.7** When air coolers are specified, they shall be in accordance with API Standard 661.

3.8.8 Unless otherwise specified, air-cooled heat exchangers used for intercoolers shall have automatic temperature control. This control may be accomplished by means of louvers, variable-speed fans, variable-pitch fans, bypass valves, or any combination of these. Proposed control systems will be approved by the purchaser.

CAUTION: Caution should be exercised in applying air-cooled heat exchangers because of their susceptibility to pulsation-induced vibration in systems and structures. Mechanical natural frequencies should not be coincident with pulsation frequencies in the heat exchanger systems.

3.8.9 Unless otherwise specified, double-pipe intercoolers and aftercoolers may be furnished. A finned double-pipe design may be furnished only when specifically approved by the purchaser.

● **3.8.10** Intercoolers shall be either machine mounted or separately mounted, as specified.

● **3.8.11** Materials of construction shall be those specified on the data sheets.

● **3.8.12** When specified, condensate separation and collection facilities shall be furnished by the vendor and shall include the following:

a. A drain system on the boot of the knockout vessel with an automatic level control and a manual bypass around the control valve.
b. An armored gauge glass (with isolating valves and blowdown valve) on the collection pot.
c. Collection pots sized to provide an agreed-on holding capacity and a 5-minute time span between high-level alarm and trip based on the expected normal liquid condensation rate.
d. Separate connections and level switches for high-level alarm and trip on the collection pot.

● **3.8.13** When specified, the vendor shall furnish the fabricated piping between the compressor stages and the intercoolers and aftercoolers. Interstage piping shall conform to the requirements of 3.7.6.

3.9 Pulsation and Vibration Control Requirements

3.9.1 GENERAL

The basic means used to control detrimental pulsations and vibrations are the following:

a. Pulsation suppression devices such as pulsation filters and attenuators (including those of proprietary commercial designs based on acoustical suppression techniques), volume bottles without internals, choke tubes, orifice systems, and selected piping configurations.
b. System design based on studies of the interactive effects of pulsations and the attenuation requirements for satisfactory piping vibration, compressor performance, and valve life.
c. Mechanical restraints such as type, location, and number of pipe hold-downs.

Note: Completion of purchaser requirements for the pulsation suppressors (see Appendix A) is essential to the vendor to quote and fabricate these accessories.

3.9.2 DESIGN APPROACHES

● **3.9.2.1** The purchaser will specify the design approach for pulsation and vibration control. The purchaser will also indicate when existing compressors and their associated piping systems are to be included in the acoustical simulation (see 3.9.2.8). One of these three techniques is normally used.

● a. *Design Approach 1: Pulsation control through the use of pulsation suppression devices designed using proprietary and/or empirical analytical techniques to meet pulsation levels required in 3.9.2.5 based on the normal operating condition.* If specified, a simplified analysis of the purchaser's piping system shall be performed to determine critical piping lengths that may be in resonance with acoustical harmonics. Acoustical simulation analysis is not required.

b. *Design Approach 2: Pulsation control through the use of pulsation suppression devices and proven acoustical simulation techniques in conjunction with mechanical analysis of pipe runs and anchoring systems (clamp design and spacing) to achieve control of vibrational response.* This approach includes the evaluation of acoustical interaction between compressor, suppression devices, and piping, including pulsation effects on compressor performance and an evaluation of acoustical-shaking forces as specified in 3.9.2.6, Items a and b, to meet the requirements of 3.9.2.7. Thermal flexibility effects should be considered in the piping design.

Note: The interactive acoustical studies may be by analog simulation, digital simulation, or a combination of the two.

c. *Design Approach 3: The same as Design Approach 2, but also employing a mechanical analysis of the compressor cylinder, compressor manifold, and associated piping systems including interaction between acoustical and mechanical system responses as specified in 3.9.2.6.* The acoustical effects of the compressor valves and gas passages interaction are studied, and performance is verified. Both acoustical and mechanical methods are used to arrive at the most efficient and cost effective plant design in compliance with the requirements of 3.9.2.7.

Note: See Appendix M for the minimum procedures required to meet the requirements of 3.9.2. See Appendix N for guidelines on compressor gas piping design and preparation for an acoustical simulation analysis.

3.9.2.2 Pulsation suppression devices and techniques in accordance with Design Approaches 1, 2, and 3 shall satisfy the criteria in 3.9.2.2.1 through 3.9.2.2.5.

3.9.2.2.1 Pulsation-induced vibration and/or mechanically induced vibration shall not cause a cyclic stress level in excess of the endurance limits of materials used for components subject to these cyclical loads. [For carbon steel pipe with an operating temperature below 371°C (700°F), the peak-to-peak cyclic stress range shall be less than 179.2 megapascals (26,000 pounds per square inch) considering all stress concentration factors present and with all other stresses within applicable code limits.]

Note: Cyclic stresses normally are not calculated for Design Approaches 1 and 2; however, these criteria should still be used as guidelines for Design Approaches 1 and 2.

3.9.2.2.2 For Design Approach 1 and for initial commercial sizing, pulsation suppression devices shall have minimum suction surge volume and minimum discharge surge volume (not taking into account liquid collection chambers), as determined from Equations 2 and 3.

In SI units:

$$V_s = 8.1\,PD\left(\frac{KT_s}{M}\right)^{\frac{1}{4}} \quad (2)$$

$$V_s \geq V_d$$

$$V_s \geq 0.028 \text{ cubic meter}$$

And in customary units:

$$V_s = 7\,PD\left(\frac{KT_s}{M}\right)^{\frac{1}{4}}$$

$$V_s \geq V_d$$

$$V_s \geq 1 \text{ cubic foot}$$

Where:

V_s = minimum required suction surge volume, in cubic meters (cubic feet).
K = isentropic compression exponent at average operating gas pressure and temperature.
T_s = absolute suction temperature, in Kelvin (degrees Rankine).
M = molecular weight.
PD = total net displaced volume per revolution of all compressor cylinders to be manifolded in the surge volume, in cubic meters per revolution (cubic feet per revolution).

$$V_d = 1.6\left(\frac{V_s}{(R)^{\frac{1}{k}}}\right) \quad (3)$$

$$V_d \leq V_s$$

$$V_d \geq 0.028 \text{ cubic meter}$$

And in customary units:

$$V_d = 1.6\left(\frac{V_s}{(R)^{\frac{1}{k}}}\right)$$

$$V_d \leq V_s$$

$$V_d \geq 1 \text{ cubic foot}$$

Where:

R = stage pressure ratio at cylinder flanges.
V_d = minimum required discharge surge volume, in cubic meters (cubic feet).

Note: R is calculated by dividing the absolute discharge pressure by the absolute suction pressure.

The internal diameter of the surge volume shall be based on the minimum surge volume overall length required to manifold the compressor cylinders. For a single-cylinder surge volume, the ratio of surge volume length to internal diameter shall not exceed 4.0. The inside diameter of spherical volumes shall be calculated directly from the volumes determined by Equations 2 and 3.

Note: Equations 2 and 3 are intended to ensure that reasonably sized pulsation suppression devices are included with the compressor vendor's proposal and should provide satisfactory sizes for most applications. In some instances, however, altering the sizes according to the simulation study employed by Design Approaches 2 and 3 will be necessary. Sizing requirements may be substantially influenced by operating parameters, interaction among elements of the overall system, and mechanical characteristics of the compressor manifold system. The magnitude of the effects of these factors cannot be accurately predicted at the outset.

Some compressor applications require the use of properly designed low-pass acoustical filters. A low-pass acoustical filter consists of two volumes connected by a choke tube. The volumes may be made up of two separate suppressors or one suppressor with an internal baffle. A preliminary sizing procedure for sizing low-pass acoustical filters is presented in Appendix O. The design must be confirmed by an acoustical simulation.

3.9.2.2.3 Unless other criteria (such as loss of compressor efficiency) are specified, the unfiltered peak-to-peak pulsation level at the compressor cylinder flange, as a percentage of average absolute line pressure, shall be limited to 7 percent or that percentage determined by Equation 4, whichever is lower.

$$P_{cf}(\%) = 3R \qquad (4)$$

Where:

$P_{cf}(\%)$ = maximum allowable unfiltered peak-to-peak pulsation level, as a percentage of average absolute line pressure at the compressor cylinder flange.
R = stage pressure ratio.

Where maximum pulsation levels exceed these values and reasonal modifications are used, higher limits may be agreed on by the purchaser and the compressor vendor.

Note: The frequencies, phase relationships, and amplitudes of pressure pulsation at the compressor valves can significantly affect compressor performance and valve life. Pulsation levels measured at the compressor cylinder flange will usually not be the same as the levels at the valves. Experience has shown, however, that pulsation limits at the cylinder flanges, as specified above, result in compressor performance within the tolerances stated in this standard.

3.9.2.2.4 Unless otherwise specified, the pressure drop based on steady flow through a pulsation suppression device at the manufacturer's rated capacity shall not exceed 0.25 percent of the average absolute line pressure at the device or the percentage determined by Equation 5, whichever is higher.

$$\Delta P(\%) = \frac{1.67(R-1)}{R} \qquad (5)$$

Where:

$\Delta P(\%)$ = maximum pressure drop based on steady flow through a pulsation suppression device, as a percentage of the average absolute line pressure at the inlet of the device.

When a moisture separator is an integral part of the pulsation suppression device, the pressure drop based on steady flow through such a device at the manufacturer's rated capacity shall not exceed 0.33 percent of the average absolute line pressure at the device or the percentage determined by Equation 6, whichever is higher.

$$\Delta P(\%) = \frac{2.17(R-1)}{R} \qquad (6)$$

3.9.2.2.5 Operation with alternative gases, alternative conditions of service, or alternative start-up conditions shall be specified on the data sheets, and pulsation suppression devices shall be mechanically suitable for all specified conditions and gases. When a compressor is to be operated on two gases of dissimilar molecular weights (for example, hydrogen and nitrogen), pulsation levels at the cylinder flanges and elsewhere in the entire piping system shall be optimized for the gas on which the unit must operate for the greater length of time. Pulsation levels shall be reviewed for all specified alternative gases, operating conditions, and loading steps to assure that pulsation levels will be acceptable under both operating conditions.

3.9.2.3 The following limits shall apply to the normal operating conditions:

a. For Design Approaches 1, 2, and 3, allowable pulsations at cylinder flanges shall not exceed the value calculated from Equation 4.
b. For Design Approach 1, allowable pulsations at the line side of the suppressor shall not exceed the value calculated from Equation 7.
c. For Design Approaches 2 and 3, allowable pulsations in the piping system shall not exceed that allowed by 3.9.2.7.

Note: The purchaser should be aware that the application of these pulsation limits to a new compressor that will operate in parallel with existing compressor(s) could result in pulsation levels higher than those allowed in this standard (see 3.9.2.8).

3.9.2.4 The chart in Figure 4 gives guidelines for specifying the appropriate design approach. For services beyond the chart range, Design Approach 3 should be used.

Note: Employment of knowledgeable personnel to confirm the design approach selection is encouraged. This confirmation is especially important if the compressor interacts with another compressor and/or the compressor is required to operate on gases of significantly different molecular weights or in other critical applications (such as those with process flow meters).

3.9.2.5 Pulsation suppression devices used in accordance with Design Approach 1 shall limit peak-to-peak pulsation levels at the line side of the pulsation suppression device to a value determined by Equation 7.

In SI units:

$$P_l(\%) = \frac{4.1}{(P_L)^{\frac{1}{3}}} \quad (7)$$

And in customary units:

$$P_l(\%) = \frac{10}{(P_L)^{\frac{1}{3}}}$$

Where:

$P_l(\%)$ = maximum allowable peak-to-peak pulsation level at any discrete frequency, as a percentage of average absolute pressure.

P_L = average absolute line pressure, in bar (pounds per square inch).

3.9.2.6 Acoustical evaluation for Design Approaches 2 and 3 shall be accomplished with proven acoustical simulation techniques that model the compressor cylinders, pulsation suppression devices, piping, and equipment system and that consider dynamic interaction among these elements. Mechanical evaluation for Design Approach 3 shall include an analysis of compressor cylinder manifold and piping systems, including pulsation suppression devices, and the study of the interaction between acoustical and mechanical system responses at specified operating conditions. In addition to the requirements stipulated in 3.9.2.2, the following steps are required to accomplish the proper evaluation for Design Approaches 2 and 3 (see also Appendix M).

a. *Determination of the acoustical response of the system, including the amplitude and the spectral frequency distribution of pulsations.* This analysis shall ensure minimum degradation of cylinder performance by the effects of dynamic interaction among cylinder, suppression device, and piping.

b. *Determination and control of acoustical unbalanced forces produced within the pulsation suppression devices, piping, heat exchangers, or vessels with internals.* Location of inlet and outlet nozzles and internal baffles and choke tubes shall be arranged to minimize these forces. See 3.9.3.9, 3.9.3.17, and 3.9.4.

c. *Determination and control of significant pulsation amplitudes at the compressor cylinder valves.* Of particular importance are the frequencies that fall within the range of the mechanical natural frequencies of the valves, generally in the range of 50–100 hertz. Acoustical responses within this range in the valve ports or at the valves have been known to cause valve failures.

d. *For Design Approach 3, determination of the mechanical response of the piping system, including mechanical natural frequencies and mode shapes of the compressor cylinder-manifold system.* This analysis shall also establish allowable limits for pulsation-induced shaking forces in the piping system based on the cyclic stress levels they can produce.

e. *For Design Approach 3, determination of the required pulsation suppression based on acoustical and mechanical responses and their interactions.* To obtain the desired control of vibration and pulsation, selective use should be made of both acoustical and mechanical control techniques. These techniques include the elimination of coincidences between acoustical and mechanical resonant frequencies; acoustical filtering techniques; and changes in mechanical configurations.

Note: When evaluating the need for possible modifications to the piping and/or pulsation suppression devices during an acoustical simulation study, consideration should be given to acoustical-shaking forces and the effect of pulsations on compressor performance. When Design Approach 3 is used, consideration should also be given to mechanical system responses and the use of mechanical vibration control techniques. Pulsation levels (expressed as a percentage of line pressure) should not be used as the sole criterion for making modifications to the piping and/or pulsation suppression devices.

3.9.2.7 For Design Approaches 2 and 3, based on normal operating conditions, the peak-to-peak pulsation levels in the initial suction, interstage, and final discharge piping systems

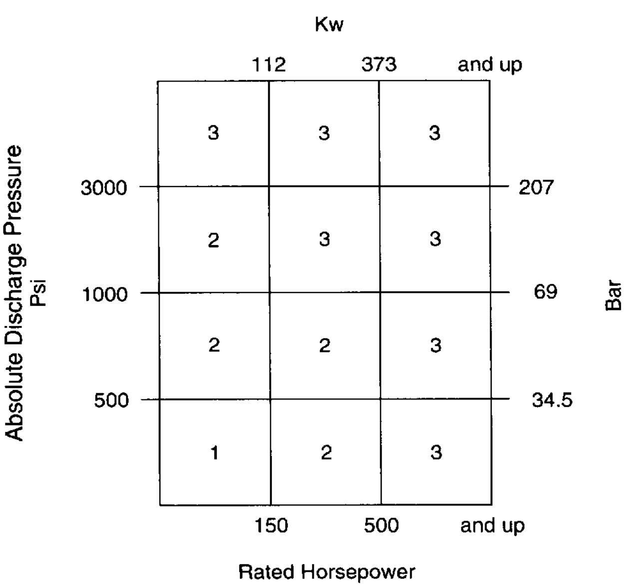

Figure 4—Guidelines for Specifying the Appropriate Design Approach for Pulsation and Vibration Control

beyond pulsation suppression devices shall satisfy the requirements of 3.9.2.2. For systems operating at absolute line pressures between 3.5 and 200 bar (between 50 and 3000 pounds per square inch), this requirement is usually satisfied when the peak-to-peak pulsation level of each individual pulsation component is limited to that calculated by Equation 8.

In SI units:

$$P_1(\%) = \frac{397.1}{(P_L\ ID\, f)^{\frac{1}{2}}} \quad (8)$$

And in customary units:

$$P_1(\%) = \frac{300}{(P_L\ ID\, f)^{\frac{1}{2}}}$$

Where:

$P_1(\%)$ = maximum allowable peak-to-peak level of individual pulsation components corresponding to the fundamental and harmonic frequencies, as a percentage of average absolute line pressure (see 3.9.2.8).
ID = inside diameter of line pipe, in millimeters (inches).
f = pulsation frequency, in hertz.

The pulsation frequency f is derived from Equation 9:

$$f = \frac{rpm\ N}{60} \quad (9)$$

Where:

rpm = machine speed, in revolutions per minute.
N = the integer 1, 2, 3 ... that corresponds to the fundamental frequency and harmonics of rpm.

For absolute pressures lower than 3.5 bar (50 pounds per square inch), use the peak-to-peak levels in bar (pounds per square inch) (not as a percentage) of individual pulsation components calculated for 3.5 bar (50 pounds per square inch absolute). For pressures greater than 200 bar (3000 pounds per square inch absolute), the corresponding calculated cyclic stresses shall be carefully evaluated to assure compliance with 3.9.2.2.1.

Note: Pulsation limits may exceed the levels defined by 3.9.2.7; however, that all other requirements in 3.9.2.2 are satisfied must be demonstrated.

•**3.9.2.8** When the compressor unit is to be installed in parallel with other compressor units, an interactive acoustical simulation study should normally be specified. If the interactive study indicates a requirement for modifications to piping or pulsation suppression devices to meet the requirements of 3.9.2.7, modifications shall be based on agreement by the purchaser and the vendor.

3.9.2.9 A written report on the control of pulsation and vibration shall be furnished to the purchaser. Compliance with the requirements of 3.9 for the specified Design Approach shall be documented.

3.9.3 PULSATION SUPPRESSION DEVICES

3.9.3.1 As a minimum, pulsation suppression equipment shall be designed and fabricated in accordance with Section VIII, Division 1, of the ASME Code. When specified, the pulsation suppressors shall be stamped with the ASME Code symbol and registered with the National Board of Pressure Inspectors. If another code is required, this code shall be noted on the data sheets.

3.9.3.2 The maximum allowable working pressure for any component shall not be less than the setting of the relief valve serving that component.

CAUTION: Purchasers should be aware of the overpressure hazards of closing suction block valves on idle compressors. Suction-side equipment between the block valve and the compressor cylinder should be rated for discharge pressure or have a protective relief valve.

3.9.3.3 All materials in contact with process gases shall be compatible with the gases being handled. The corrosion allowance for carbon steel pulsation suppression equipment shall be a minimum of 3.2 millimeters (1/8 inch) unless otherwise specified on the data sheet. Regardless of materials, all shells, heads, baffles, and partitions shall have a minimum thickness of 9.6 millimeters (3/8 inch). Welding procedures shall be provided. (See Vendor Data section in Appendix F, Item 47.)

● **3.9.3.4** When specified, all butt welds shall be 100-percent radiographed.

3.9.3.5 All flanged branch connections shall be reinforced so that the reinforcement provides a metal area equal to the cut-away area regardless of the metal thickness in the connection wall. Stress concentration factors shall be considered to assure compliance with 3.9.2.2.

3.9.3.6 Suction pulsation suppression devices, not provided with a moisture removal section, shall be designed to prevent trapping of liquid. When specified, the suction pulsation suppression device(s) shall include a final moisture removal section as an integral part of the vessel. The moisture removal section shall have a reservoir extending below the device shell and shall be equipped with a 1-inch Nominal Pipe Size drain, gauge glass connections, and a shutdown switch connection. The connections shall be flanged and fitted with blinds. When specified, the drain valve, gauge glass, and shutdown switch shall be furnished by the vendor. The moisture removal section shall remove 99 percent of all droplets of 10 microns or larger. Pressure drop shall be as defined in 3.9.2.2.4.

3.9.3.7 The nozzle length from the shell of the pulsation suppression device to the cylinder flange shall be held to a minimum that is consistent with thermal flexibility and pulsation requirements. The nozzle area shall be at least equal to the area for the nominal compressor cylinder flange size. Adequate space shall be allowed for access to and maintenance of the cylinder's working parts.

3.9.3.8 Manufacturing tolerances and fit-up procedures for pulsation suppression devices, compressor cylinder nozzle connections and line connections, shall be adequate to allow bolting of flanges without the use of devices such as jacks and come-alongs, which may result in excessive stresses, misalignment, or rod runout. When two or more cylinders are to be connected to the same pulsation suppression device, the flanges shall be fitted to aligned cylinders at the compressor vendor's shop and welded in place to assure proper final alignment and to minimize residual stresses. This procedure is especially important for ring joint flanges.

3.9.3.9 Orientation of the pulsation suppression devices and their nozzles will be specified by the purchaser, subject to practical limitations imposed by the vendor and dynamic design requirements. Ratings, types, and arrangements of all connections shall be agreed on by the purchaser and the vendor.

3.9.3.10 Pressure test connections of NPS 3/4 shall be provided at each pulsation suppressor inlet and outlet nozzle. An external drain connection of at least NPS 1 shall be provided for each compartment where practical. Where multiple drains are impractical, circular notched openings in the baffles that are located at the low point of the vessel wall may be used with the purchaser's approval. The effect of such drain openings on the performance of the pulsation suppression device must be considered. Arrangement of internals shall ensure that liquids will flow to drain connections under all operating conditions.

● **3.9.3.11** The cylinder nozzle of each discharge pulsation suppression device shall be provided with two connections located to permit, without interference, the purchaser's installation of thermowells of at least NPS 1 for a high-temperature alarm or shutdown element and a dial thermometer. When specified, a thermowell connection of at least NPS 1 shall also be provided for the cylinder nozzle of each suction pulsation suppressor.

3.9.3.12 Flanged connections NPS 1 and smaller, although reinforced in accordance with 3.9.3.5, shall be designed to minimize overhung weight and shall be gussetted back to the main pipe or reinforcing pad in at least two planes to avoid breakage resulting from vibration.

3.9.3.13 Main connections for the compressor cylinder and process line shall be fitted with weld-neck flanges unless otherwise specified by the purchaser. Pulsation suppressors 450 millimeters (18 inches) and greater in internal diameter shall have studded pad-type inspection openings at least 150 millimeters (6 inches) in diameter and complete with blind flanges and gaskets to provide access to each compartment. For suppressors less than 450 millimeters (18 inches) in internal diameter, 100-millimeter (4-inch) studded pad-type inspection openings are permitted.

Note: Inspection openings shall be located in positions, such as on both sides of the baffles, that provide maximum capability to visually inspect critical welds.

3.9.3.14 Pulsation suppression device connections other than those covered by 3.9.3.13 shall be flanged or threaded as specified on the data sheets. All threaded fittings shall have a minimum rating of Class 6000.

3.9.3.15 Flanges shall be in accordance with ASME B16.5; except that lap-joint and slip-on flanges are not allowed. The finish of the gasket contact surface for flanges other than the ring joint type shall be an R_a of 3.2–6.4 micrometers (125–250 microinches). Either a serrated-concentric finish or a serrated-spiral finish having a pitch of 0.6–1.0 millimeter (24–40 grooves per inch) shall be used. The surface finish of the gasket grooves of ring joint connections shall conform to ASME B16.5.

● **3.9.3.16** When specified, provisions shall be made for attaching insulation. All connections and nameplates shall be arranged to clear the insulation.

3.9.3.17 All internals of pulsation suppression devices shall be designed, fabricated, and supported with consideration of the possibility of high acoustical-shaking forces. Dished baffles shall be used in lieu of flat baffles. The same welding procedures as applicable to external welds shall be followed. Full-penetration welds shall be used for the attachment of the baffles to the pulsation suppressor shell.

3.9.3.18 All butt welds shall be full-penetration welds.

3.9.3.19 Internal surfaces of carbon steel pulsation suppression devices shall be covered with a coating of phenolic and vinyl resins that are suitable for the service conditions.

3.9.3.20 A stainless steel nameplate shall be provided on each pulsation suppression device. The manufacturers' standard data, the purchaser's equipment item number, and the purchaser's purchase order number shall be included.

● 3.9.4 SUPPORTS FOR PULSATION SUPPRESSION DEVICES

If specified, supports for the pulsation suppression devices and vendor-supplied piping shall be furnished by the vendor. These supports shall be designed considering static loading (including piping), acoustical shaking forces and mechanical responses; and shall not impose harmful stresses on the compressor, piping system, or pulsation suppression devices to which they are attached. In calculating stress levels, the compressor frame growth and the flexibilities of the frame, crosshead guide, distance piece, flange, and branch connection shall be considered. Compliant (resilient) supports having inherent vibratory dampening characteristics are preferred to accommodate thermal expansion. Loading of compliant supports shall be adjustable. Noncompliant supports shall be designed to permit adjustment by the purchaser while in operation. Spring supports shall not be used unless specifically approved by the purchaser.

Note: The support foundation should be integrated with the compressor foundation as much as possible. When noncompliant adjustable supports are used, they should be adjusted by the purchaser at normal operating conditions.

• 3.10 Air Intake Filters

For air compressors taking suction from the atmosphere, a dry-type air intake filter-silencer suitable for outdoor mounting shall be provided by the vendor unless otherwise specified. The purchaser will state which special design details, if any, are required.

CAUTION: The vendor shall bring to the purchaser's attention any hazards he believes could result from complying with the purchaser's specifications.

As a minimum, the following features should be considered in the design of the filter-silencer:

a. Micron particle rating.
b. In-service cleanability.
c. Corrosion protection of filter and of internal surface of inlet piping.
d. Avoidance of internal threaded fasteners.
e. Taps for measuring filter pressure differential.

3.11 Special Tools

3.11.1 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 with complete instructions for their use. For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be agreed on by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

• **3.11.2** Special tools for reciprocating compressors shall include the following:

a. Mandrels for fitting wear bands on nonsegmental pistons.
b. A lifting and lowering device for removal and insertion of valve assemblies that weigh more than 16 kilograms (35 pounds).
c. A crosshead removal and installation tool.
d. When specified, hydraulic tensioning tools.

3.11.3 When special tools are provided, they shall be packaged in separate, rugged metal box or boxes and marked "special tools for (tag/item number)." Each tool shall be stamped or tagged to indicate its intended use.

3.11.4 Compressors rated over 150 kilowatts (200 brake horsepower) shall be provided with a suitable manual barring device for maintenance. For compressors rated over 750 kilowatts (1000 brake horsepower), a pneumatic-driven barring device shall be furnished. In general, pneumatic barring devices should be considered for compressors with a peak bar-over torque requirement of 1600 newton-meters (1200 foot-pounds) or more. The vendor shall furnish a complete description of the barring device including such factors as method of operation to be used (for example, manual engagement and automatic disengagement on start of compressor), lockout signals required, location, guards, and air or power required.

• **3.11.5** When specified, each compressor shall be fitted with a device that will allow the shaft to be locked in position during maintenance. The device shall allow locking of the shaft in multiple positions, as necessary for maintenance. The device shall be fitted with a limit switch.

Note: The purchaser should interlock this limit switch with the driver.

SECTION 4—INSPECTION, TESTING, AND PREPARATION FOR SHIPPING

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 to the purchaser before conducting any inspection or test that the purchaser has specified as to be witnessed or observed.

● **4.1.4** The purchaser will specify the extent of his participation in the inspection and testing and the amount of advance notification he requires. Five working days is usually considered adequate notice for inspections and tests (see 4.3.1.3).

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

4.1.4.2 The term *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 tests, the term *witnessed* requires written notification of a successful preliminary test.

4.1.4.3 The term *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 is required for a witnessed test.)

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

● **4.1.6** When specified, the purchaser's representative, the vendor's representative, or both shall indicate compliance in accordance with the inspector's checklist (Appendix K) by initialing, dating, and submitting the completed checklist to the purchaser before shipment.

4.1.7 The purchaser's representative shall have access to the vendor's quality-control 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 twenty years either for examination by the purchaser or his representative on request or for reproduction if necessary.

a. Necessary certification of materials, such as mill test reports.
b. Purchase specifications for all items on bills of materials.
c. Test data to verify that the requirements of the specification have been met.
d. Results of documented tests and inspections, including fully identified records of all heat treatment and radiography.
e. When specified, final-assembly, maintenance, and running clearances.
f. A complete set of manuals with drawings and schematics.

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 2.14.7.1, 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**

When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 4.2.2.2 through 4.2.2.5 shall apply unless other 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 through 4.2.2.5.

Regardless of the generalized limits in 4.2.2.2 through 4.2.2.5, it shall be the vendor's responsibility to review the design limits of the equipment and, if necessary, apply more stringent requirements. Defects that exceed the limits imposed in 4.2.2.2 through 4.2.2.5 shall be removed to meet the quality standards cited, as determined by the inspection method specified.

Note: Care should be taken in the use of acceptance criteria for iron castings. Criteria developed for other materials may not be applicable.

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 steel castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code. The acceptance standard used for steel forgings shall be ASTM A 388.

4.2.2.3.3 All crankshafts shall be ultrasonically tested in accordance with ASTM A 503 after machining, but before drilling.

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 8.

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.

Table 8—Maximum Severity of Defects in Castings

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

● **4.2.3.2** When the oil system is specified to be run in the manufacturer's shop, it shall meet the test screen cleanliness requirements specified in API Standard 614.

● **4.2.3.3** 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 vessels or exchangers are closed, or piping is finally assembled.

● **4.2.3.4** 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 zones. The method, extent, documentation, and witnessing of the testing shall be agreed on by the purchaser and the vendor.

4.2.3.5 Unless otherwise specified, the equipment components or surfaces subject to corrosion shall be coated with the vendor's standard rust preventive immediately after inspection. Temporary rust preventive shall be easily removable with common petroleum solvents, and the equipment shall be closed promptly on the purchaser's acceptance thereof. See 4.4.3 for details.

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.

4.3.1.2 At least 6 weeks before the first scheduled test, the vendor shall submit to the purchaser, for his review and comment, detailed procedures for all running 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 AND GAS LEAKAGE TESTS

4.3.2.1 Pressure-containing parts (including auxiliaries) shall be pressure tested hydrostatically with liquid at a higher temperature than the nil-ductility transition temperature of the material being tested and at the following minimum test pressures:

a. *For cylinder gas passages and bore, $1^1/_2$ times MAWP, but not less than the gauge pressure of 1.4 bar (20 pounds per square inch).*
b. *For cylinder cooling jackets and packing cases, $1^1/_2$ times the specified cooling water pressure, but not less than the gauge pressure of 8.0 bar (115 pounds per square inch).*

c. *For piping, pressure vessels, filters, and other pressure-containing components, 1½ times MAWP or in accordance with applicable code, but not less than the gauge pressure of 1.4 bar (20 pounds per square inch).*

The tests specified in Items a and b shall be performed prior to the installation of the cylinder liner.

Compressor cylinders shall be tested as assembled components using gaskets of the same style and design, along with the heads, valve covers, clearance pockets, and fasteners that will be supplied with the finished cylinder.

Note: For gas-pressure-containing parts, the hydrostatic test is a test of the mechanical integrity of the component and is not a valid gas leakage test.

4.3.2.2 The appropriate gas leakage test indicated by the following list shall be performed to ensure that the components do not leak process gas. The leakage test shall be conducted with the components thoroughly dried and unpainted. Compressor cylinders shall be leak-tested without liners, but with the same assembled component requirements as in 4.3.2.1.

a. Pressure-containing parts, such as compressor cylinders and clearance pockets handling gases with a maximum molecular weight of 12 or gases containing more than 0.1-mole-percent hydrogen sulfide, shall have (in addition to the hydrostatic test specified in 4.3.2.1) a pressure test with helium performed at the MAWP. Leak detection shall be by helium probe or by submergence of the part in water. The water shall be at a higher temperature than the nil-ductility transition temperature of the material being tested. The internal pressure shall be maintained, while the part is submerged, at the maximum working pressure. The amount of leakage must be zero (see 4.3.2.6).
b. Cylinders handling gases other than those described in Item a shall have a gas leakage test in accordance with Item a, except that the test gas shall be air or nitrogen.

4.3.2.3 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 the operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping or to those given in Section VIII, Division 1, of the ASME Code for vessels. The pressure thus obtained shall then be used as the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

4.3.2.4 Where applicable, tests shall be in accordance with the ASME Code. In the event that the test pressure in the code is inconsistent with the test pressure in this standard, the higher pressure shall govern.

4.3.2.5 The chloride content of liquids that are used to test austenitic stainless steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts immediately after the test.

4.3.2.6 Tests shall be maintained for a period of time sufficient to permit complete examination of parts under pressure. The hydrostatic and gas leakage tests shall be considered satisfactory when neither leaks nor seepage through the component or component joints is observed for a minimum of 30 minutes. Large, heavy castings may require a longer testing period, to be agreed on by the purchaser and the vendor.

4.3.2.7 Test gaskets shall be identical to those required for the service conditions.

4.3.3 MECHANICAL RUNNING TEST

4.3.3.1 All compressors, drivers, and gear units shall be shop tested per the vendor's standard (see 5.2.3, Item r).

● **4.3.3.2** When specified, the units, including integral auxiliary system packages, shall receive a 4-hour mechanical running test before shipment. The test shall prove mechanical operation of all auxiliary equipment and of the compressor, reduction gear (if any), and driver as a complete unit. The compressor does not have to be pressure loaded for this test. The procedure for this running test shall be as agreed on by the purchaser and the vendor.

4.3.3.3 All oil pressures, viscosities, and temperatures for a specific unit being tested shall be within the range of operating values recommended in the vendor's operating instructions for the unit.

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

● **4.3.3.5** Auxiliary equipment not integral with the unit—such as auxiliary oil pumps, oil coolers, filters, intercoolers, and aftercoolers—need not be used for any compressor shop tests unless specified. When specified, auxiliary system consoles shall receive both an operational test and a 4-hour mechanical running test before shipment. The procedure for this running test shall be as agreed on by the purchaser and the vendor.

● **4.3.3.6** The purchaser shall specify if dismantling for inspection (other than that required by evidence of malfunctioning during testing) is required.

4.3.4 OTHER TESTS

4.3.4.1 A bar-over test of the frame and cylinders shall be made in the vendor's shop to verify piston end clearances and rod runout. All compressor cylinder valves must be in place for the final bar-over test to demonstrate no piston interference. Vertical and horizontal piston-rod runout (cold) at crosshead and packing ends shall also be measured during this test. Refer to 2.6.2.1 and 2.8.6. Bar-over test results shall become a part of the purchaser's records (Appendix F, Item 60).

● **4.3.4.2** When specified, all machine-mounted equipment, prefabricated piping, and appurtenances furnished by the vendor shall be fitted and assembled in the vendor's shop. The vendor shall be prepared to demonstrate that the equipment is free of harmful strains.

4.3.4.3 All compressor suction and discharge cylinder valves shall be leak-tested per the vendor's standard procedure.

4.4 Preparation for Shipment

● **4.4.1** Equipment shall be suitably prepared for the type of shipment specified, including blocking of the crankshaft. The preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment. If storage for a longer period is specified, the purchaser will consult with the vendor regarding recommended procedures to be followed.

4.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

4.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include that specified in 4.4.3.1 through 4.4.3.14.

4.4.3.1 Equipment shall be completely free of water before any shipment preparation.

4.4.3.2 Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates.

4.4.3.3 Exterior machined surfaces shall be coated with a suitable rust preventive.

4.4.3.4 The interior of the equipment shall be clean; free from scale, welding spatter, and foreign objects; and sprayed or flushed with a suitable rust preventive that is oil soluble or that can be removed with solvent. The rust preventive shall be applied to all openings while the machine is slow-rolled. In lieu of soluble rust preventive, a permanently applied rust preventive may be used with prior approval by the purchaser.

4.4.3.5 Internal areas of frames, bearing housings, and oil system equipment such as reservoirs, vessels, and piping shall be coated with an oil-soluble rust preventive or, with the purchaser's prior approval, a permanent rust preventive.

CAUTION: Any paint exposed to lubricants must be oil resistant. When synthetic lubricants are used, special precautions must be taken to assure compatibility with the paint.

4.4.3.6 Flanged openings shall be provided with metal closures at least 5.0 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.

4.4.3.7 Threaded openings shall be provided with steel caps or round-head steel plugs in accordance with ASME B16.11. The caps or plugs shall be of material equal to or better than that of the pressure casing. In no case shall nonmetallic (such as plastic) caps or plugs be used.

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

4.4.3.9 Lifting points and the center of gravity shall be clearly identified on the equipment package. The vendor shall recommend the lifting arrangement.

● **4.4.3.10** The equipment shall be crated for domestic or export shipment as specified. Lifting, load-out, and handling instructions shall be securely attached to the exterior of the largest package in a well-marked weatherproof container. All special lifting devices and rigging shall be supplied with the unit. Upright position, lifting points, weight, and dimensions shall be clearly marked on each package.

4.4.3.11 The equipment shall be identified by item and serial numbers. Material shipped separately shall be identified by 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 outside of the shipping container.

4.4.3.12 Any cylinders, heads, packing cases, packing, pistons, rods, crossheads and shoes, crosshead pins, bushings, and connecting rods that are dismantled for separate shipment or that are to be shipped as spare parts shall be sprayed with rust preventive, wrapped with moisture-proof sheeting, and boxed in substantial crating to prevent damage in shipment to or storage at the job site.

4.4.3.13 Exposed shafts and shaft couplings shall be wrapped with waterproof, moldable waxed cloth or volatile corrosion inhibitor (VCI) paper. The seams shall be sealed with oil-proof adhesive tape.

4.4.3.14 Exterior surfaces of pulsation suppressors, piping, and vessels shall be cleaned free of pipe scale, welding spatter, and other foreign objects. Immediately after cleaning, external surfaces shall be painted with at least one coat of the manufacturer's standard primer. Internal surfaces of pulsation suppression devices shall be completely free of scale, slag, dirt, and all foreign material and shall be finished in accordance with 3.9.3.19.

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 Bearing assemblies shall be fully protected from the entry of moisture and dirt. If volatile corrosion inhibitor crystals in bags are installed in large cavities, 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 by stainless steel wire.

4.4.6 Component parts, loose parts, and spare parts associated with a specific major item of equipment shall be individually crated for shipment and shall not be mixed with similar parts associated with another major item of equipment. For example, parts for the compressor shall not be mixed in the same crate with similar parts for the driver.

4.4.7 One copy of the manufacturer's installation manual per 5.3.7.2 shall be packed and shipped with the equipment.

SECTION 5—VENDOR'S DATA

5.1 General

5.1.1 VDDR FORM

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 F) to the address or 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 order, as well as the number and type of copies required by the purchaser.

5.1.2 DATA IDENTIFICATION

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

a. The purchaser/user's corporate name.
b. The job/project number.
c. The equipment item number and service name.
d. The inquiry or purchase order number.
e. Any other identification specified in the inquiry or purchase order.
f. The vendor's identifying proposal number, shop order number, serial number, or other reference required to completely identify return correspondence.

5.1.3 COORDINATION MEETING

Unless otherwise specified, a coordination meeting shall be held, preferably at the vendor's plant, within 4-6 weeks after the purchase commitment. The purchaser and the vendor shall jointly agree on an agenda for this meeting, which will include the following items as a mimimum:

a. The purchase order, scope of supply, and subvendor items (including spare parts).
b. A review of applicable specifications and previously agreed-on exceptions to specifications.
c. The data sheets.
d. The compressor performance (including operating limitations).
e. Pulsation suppression devices.
f. Schematics and bills of material (for major items) of lube-oil systems, cooling systems, distance pieces, and similar auxiliaries.
g. The preliminary physical orientation of the equipment, piping, and auxiliary systems.
h. Drive arrangement and driver details.
i. Instrumentation and controls.
j. Scope and detail of pulsation and vibration analysis and control requirements. (See Appendixes M and N and 3.9.2.1.)
k. Identification of items for stress analysis review by purchaser. (See 2.14.5.1.)
l. Inspection, expediting, and testing.
m. Details of functional testing.
n. Other technical items.
o. Start-up planning and training.
p. Schedules for (1) transmittal of data, (2) production, (3) testing, and (4) delivery.

5.2 Proposals

5.2.1 GENERAL

The vendor shall forward the original proposal and the specified number of copies of the proposal to the addressee stated on the inquiry documents. This proposal shall contain as a minimum both the data specified in 5.2.2 and 5.2.3 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 specific list that details and explains each deviation. The vendor shall provide details that would enable the purchaser to evaluate any alternative designs proposed. All correspondence shall be clearly identified per 5.1.2.

5.2.2 DRAWINGS

The drawings described on the VDDR form shall be included in the proposal. As a minimum, the data shown in Items a through c shall be furnished:

a. Preliminary general arrangement or outline drawing for each major skid or system showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights, and maintenance weights (indicate piece). The direction of rotation, and the size and location of major purchaser connections shall also be indicated.
b. Typical cross-sectional drawings(s) of the compressor proposed.
c. Schematics of all auxiliary systems, including the lube-oil system, the cooling system, and the distance-piece vent-and-drain system (when supplied). Auxiliary system schematic diagrams shall be marked to show which portions of the system are integral with or mounted on the major equipment and which are separate.

Note: If "typical" drawings or schematics are used, they shall be marked up to show correct weight and dimension data and to reflect the actual equipment and scope proposed.

5.2.3 TECHNICAL DATA

The data described below shall be included in the proposal:

a. *Copies of all of the purchaser's data sheets,* which include whatever information is required of the vendor in the proposal and whatever literature is required to fully describe details of the vendor's offering(s).
b. *The purchaser's noise data sheet or the form from the appendix of API Standard 615.*
c. *A copy of the VDDR form* (see Appendix F) *indicating the schedule according to which the vendor agrees to furnish the data requested by the purchaser* (see 5.3).
d. *Net and maximum operating weights, maximum shipping and erection weights with identification of the item, and the maximum normal maintenance weight with identification of the item.* These data shall be stated individually where separate shipments, packages, or assemblies are involved. Approximate data shall be clearly identified as such. These data shall be entered on the data sheets where applicable.
e. *For a compressor with a variable-speed drive, the minimum speed at which the unit may be operated continuously with the proposed lubrication system.*
f. The vendor shall specifically identify *volumetric efficiency of the active end of any cylinder if it is less than 40 percent at any specified operating condition.*

Note: Performance predictions with volumetric efficiencies below 40 percent are not always reliable.

g. *A schedule for shipment of the equipment, in weeks after receipt of the order.*
h. *A list of major wearing components showing interchangeability with other purchaser units.*
i. *A list of "start-up" spares,* which shall include—as a minimum—three lube-oil filter cartridge sets, plates and springs for each valve, one set of packing rings for each rod, one set of rings and wear bands for each piston, and all o-rings and gaskets necessary for a complete change-out of all packing rings, all piston rings, and all valves. The vendor shall add any items that his experience indicates are likely to be required on start-up.
j. *A statement of any special protection, including weather and winterizing protection, required by the compressor, its auxiliaries, and the driver (if furnished by the compressor vendor) for startup, operation, and periods of idleness under the site conditions specified.* The list should show both the protection required by the purchaser, and the protection included in the vendor's scope of supply.
k. *Complete tabulation of utility requirements*—such as those for steam, water, electricity, air, gas, and lube oil—including the quantity of lube oil and the supply pressure required, the heat load to be removed by the oil, and the nameplate power rating and operating power requirements of auxiliary drivers. Approximate data shall be defined and clearly identified as such. This information shall be entered on the data sheets.
l. *A description of the tests and inspection procedures for materials* as required by 4.2.2.
m. *Complete details of any proposed air-cooled oil cooler.*
● n. *A list of spare parts that the vendor recommends the purchaser stock for normal maintenance purposes.* (The purchaser shall specify any special requirements for long-term storage.)
o. *An itemized list of the special tools included* in the offering. The vendor shall list any metric items included in the offering.
p. *A clear description of the metallurgy of all major components of the compressor* (see 2.14.1.1 and 2.14.1.2).
q. *A full description of the standard shop tests required in 4.3 and of special tests as specified.*
r. *A list of relief valves specifying those furnished by the vendor,* as required by 3.6.4.5.1.
s. *A description of special requirements, including both those outlined in 2.5.1 and any other requirements in the purchaser's inquiry.*
● t. *When specified, a list of similar machines installed and operating under conditions analogous to those proposed.*
u. *Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.*
v. *Preliminary rod- and gas-load tabulation per 2.4.3.*

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 F. Each drawing, bill of material, manual, or data sheet shall have a title block in the lower right-hand corner that shows the date of certification, reference to all identification data specified in 5.1.2, revision number and date, and title.

5.3.1.2 The purchaser will return reviewed data submitted, and any comments, per the schedule agreed on in the VDDR form.

5.3.1.3 Review does not constitute permission from the purchaser for the vendor to deviate from any requirements in the order unless the deviations are specifically agreed on in writing.

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

5.3.2 DRAWINGS

The drawings furnished shall contain sufficient information so that when combined with the drawings and the manuals specified in 5.3.7, the purchaser can properly install, operate, and maintain the ordered equipment. Drawings shall be clearly legible, shall be identified in accordance with 5.1.2, and shall be in accordance with ASME Y14.2M. As a minimum, each drawing shall include the details for that drawing listed in Appendix F.

5.3.3 PERFORMANCE DATA

● **5.3.3.1** When specified, the vendor shall submit performance curves or tables, all as agreed on by the vendor and the purchaser: displaying power and capacity versus suction pressure with parameters of discharge pressure; showing the effects of unloading devices; showing any operating limitation; and identifying calculation input and output data.

● **5.3.3.2** Rod-load and gas-load charts for each load step that are complete per 2.4 and that include inertial forces and reversal magnitude and duration shall be furnished. When specified, the vendor shall furnish the data required for independent rod-load, gas-load, and reversal calculations.

● **5.3.3.3** When specified, the effect of valve failure on rod loads and reversals shall be calculated and furnished. The required specifics of this study shall be agreed on by the purchaser and the vendor.

● **5.3.3.4** Curves of starting speed versus torque shall be furnished for the compressor, for the motor at the rated voltage, and for the motor at the specified voltage reduction. The curve sheet shall also state separately (a) the inertia (WK^2) of the motor alone and (b) the resultant inertia (WK^2) of the driven equipment resolved to the motor shaft (if a speed variant is involved) and (c) the calculated time for acceleration to full speed at the specified voltage (see 3.1.2.7), and specified operating conditions (see 3.1.1.3 and 3.1.2.4). All curves shall be scaled in finite values. Percentages are not acceptable.

5.3.4 TECHNICAL DATA

Data shall be submitted per Appendix F and identified per 5.3.1.1. By correcting and filling out the data sheets—first with "as purchased" information and then with "as built" information—and submitting copies to the purchaser, the vendor shall provide enough information to the purchaser to enable him or her to complete the data sheets.

If any drawing comments or specification revisions necessitate a change in the data, the vendor will reissue data sheets which will result in reissue of the completed, corrected data sheets by the purchaser as part of the order specifications.

● 5.3.5 PROGRESS REPORTS

When specified, the vendor shall submit progress reports to the purchaser at the interval specified on the VDDR form (see Appendix F). The reports shall include engineering and manufacturing information for all major components. "Planned" and "actual" dates for each separate milestone shall be indicated.

5.3.6 RECOMMENDED SPARES

The vendor shall submit a complete list of spare parts including those shown in his original proposal. This list shall include recommended spare parts for all equipment and accessories supplied, with cross-sectional or assembly-type identification drawings, part numbers, and delivery times. Part numbers shall identify each part for interchangeability purposes. Standard purchased items shall be identified by the original manufacturer's numbers. The vendor shall forward this list 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 by the data specified in 5.1.2.

5.3.7 MANUALS

5.3.7.1 General

The vendor shall provide sufficient written instructions and a cross-referenced list of all drawings to enable the purchaser to correctly install, operate, and maintain all the equipment ordered. This information shall be compiled in a manual (or manuals) with a cover sheet containing all reference-identifying data required in 5.1.2, an index sheet containing section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared specifically for this installation and shall not be "typical."

5.3.7.2 Installation Manual

Any special information that is required for proper installation and that is not on the drawings shall be compiled in a manual that is separate from operating and maintenance instructions. This manual shall be forwarded at a time agreed on in the order, but not later than 30 days before shipment. The manual shall contain but not be limited to the information listed in Appendix F, all installation design data, and any other pertinent drawings or data.

5.3.7.3 Operating and Maintenance Manuals

The manual containing operating and maintenance data shall be forwarded no later than 30 days after shipment. The manual shall include sections to cover limiting operating conditions and special instructions for operations at specified extreme environmental conditions, such as temperatures. In addition, it shall include but not be limited to the information listed in Appendix F.

5.3.7.4 Technical Data Manual

A manual containing technical data relevant to the purchased equipment shall be submitted to the purchaser within 30 days of shipment. The manual shall include but not be limited to the information listed in Appendix F.

Note: This data may have been previously issued for review per the VDDR.

APPENDIX A—TYPICAL DATA SHEETS

PAGE ______ OF ______

RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

JOB NO. ______ ITEM NO. ______
PURCH. ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

FOR/USER ______ SITE/LOCATION ______ SERVICE ______ NO. REQ'D. ______

NOTE: ○ INDICATES INFO. TO BE COMPLETED BY PURCH. □ BY MANUFACTURER WITH PROPOSAL ◇ BY MANUFACTURER AFTER ORDER ⊡ BY MANUFACTURER OR PURCHASER AS APPLICABLE

COMPR. MFGR. ______ TYPE MODEL NO(S) ______ SERIAL NO(S) ______

COMPR. THROWS: TOTAL NO. ______ NO. WITH CYLS. ______ NOMINAL FRAME RATING ______ BHP @ RATED RPM OF ______

□ MAX/MIN ALLOWABLE SPEED ______ / ______ RPM

DRIVER MFGR. ______ DRIVER NAMEPLATE HP/OPERATING RPM ______ / ______

DRIVE SYSTEM: ○ DIRECT COUPLED ○ GEARED & COUPLED ○ V-BELT

TYPE OF DRIVER: ○ IND. MOTOR ○ SYN. MOTOR ○ STEAM TURBINE ○ GAS TURBINE ○ ENGINE ○ OTHER ______

NO NEGATIVE TOLERANCE APPLIES: (NNT) ○ YES - PURCHASER TO FILL IN "REQUIRED CAPACITY" LINES. ○ NO - PURCHASER TO FILL IN "MFGR.'S RATED CAP." LINES

CYLINDERS: ○ LUBE ○ NON-LUBE

○ MAX ACCEPTABLE AVG PISTON SPEED ______ FT/MIN

OPERATING CONDITIONS (EACH MACHINE)

○ SERVICE OR ITEM NO.						
○ STAGE						
○ NORM . OR ALT. CONDITION						
○ CERTIFIED PT. (√) CHECK ONE						
○ MOLECULAR WEIGHT						
○ Cp/Cv (K) @150 °F OR ______ °F						

INLET CONDITIONS AT INLET TO: ○ PULSE DEVICES ○ COMPRESSOR CYLINDER FLANGES

NOTE: ○ SIDE STREAM TO ______ STAGE(S), THESE INLET PRESSURES ARE FIXED

○ PRESSURE (PSIA) @ PUL. SUPP. INLET						
⊡ PRESSURE (PSIA) @ CYL. FLANGE						
○ TEMPERATURE (°F)						
○ REF: SIDE STREAM TEMPS (°F)						
□ COMPRESSIBILITY (Z_s)						

INTERSTAGE: INTERSTAGE Δ P INCLUDES: ○ PULSE DEVICES ○ PIPING ○ COOLERS ○ SEPARATORS ○ OTHER ______

⊡ Δ P BETWEEN STAGES, %/psi	/	/	/	/	/

DISCHARGE CONDITIONS: AT OUTLET FROM: ○ PULSE DEVICE ○ COMP CYL FLANGES ○ OTHER ______

⊡ PRESSURE (PSIA) @ CYL. FLANGE						
○ PRESSURE (PSIA) @ PUL. SUPP OUTLET						
□ TEMPERATURE, ADIABATIC, °F						
□ TEMPERATURE, PREDICTED, °F						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG})						

***REQUIRED CAPACITY**, RATED FOR PROCESS, AT INLET TO COMPRESSOR, NO NEGATIVE TOLERANCE (-0%)

○ LBS/HR CAPACITY SPECIFIED IS ○ WET ○ DRY						
○ MMSCFD/SCFM (14.7 PSIA & 60°F)						

MGFR.'S RATED CAPACITY (AT INLET TO COMPRESSOR) & BHP @ CERTIFIED TOLERANCE OF ±3% FOR CAP. & ±3% FOR BHP

⊡ LBS/HR CAPACITY SPECIFIED IS ○ WET ○ DRY						
⊡ ICFM						
⊡ MMSCFD/SCFM (14.7 PSIA & 60°F)						
□ BHP/STAGE						
□ TOTAL BHP @ COMPRESSOR SHAFT						
□ TOTAL HP INCLUDING V-BELT & GEAR LOSSES						

*CAPACITY FOR NNT

MANUFACTURER'S = REQUIRED ÷ 0.97

∴ REQUIRED = MANUFACTURER'S X 0.97

REMARKS/SPECIAL REQUIREMENTS ______

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RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

PAGE ______ OF ______

JOB NO. ______ ITEM NO. ______

REVISION ______ DATE ______

BY ______

GAS ANALYSIS AT OPERATING CONDITIONS MOLE % (BY VOLUME) ONLY								REMARKS
O SERVICE/ITEM NO.								
O STAGE								
O NORMAL OR ALT								
	MW							
AIR	28.966							
OXYGEN O_2	32.000							
NITROGEN N_2	28.016							
WATER VAPOR H_2O	18.016							
CARBON MONOXIDE CO	28.010							
CARBON DIOXIDE CO_2	44.010							
HYDRO. SULFIDE H_2S	34.076							
HYDROGEN H_2	2.016							
METHANE CH_4	16.042							
ETHYLENE C_2H_4	28.052							
ETHANE C_2H_6	30.068							
PROPYLENE C_3H_6	42.078							
PROPANE C_3H_8	44.094							
I-BUTANE C_4H_{10}	58.120							
n-BUTANE C_4H_{10}	58.120							
I-PENTANE C_5H_{12}	72.146							
n-PENTANE C_5H_{12}	72.146							
HEXANE PLUS								
AMMONIA NH_3	17.031							
HYDRO. CHLORIDE HCI	36.461							
CHLORINE CI	70.914							
CHLORIDES - TRACES								
☐ CALCULATED MOL WT.								
☐ Cp/Cv (K) @ 150° OR ______ °F								

NOTE: IF WATER VAPOR AND/OR CHLORIDES ARE PRESENT, EVEN IN MINUTE TRACES, IN THE GAS BEING COMPRESSED, IT MUST BE INCLUDED ABOVE.

APPLICABLE SPECIFICATIONS

O API-618-RECIPROCATING COMPRESSORS FOR PETROLEUM, CHEMICAL AND GAS INDUSTRY SERVICES

NACE MR-0175 (2.14.1.10)

O ______

O ______

O ______

O ______

O ______

O ______

O ______

O ______

O ______

SITE/LOCATION CONDITIONS

ELEVATION ______ FT BAROMETER ______ PSIA AMBIENT TEMPS: MAX ______ °F MIN ______ °F

O MIN DESIGN METAL TEMP ______ °F (2.14.8.1) RELATIVE HUMIDITY: MAX: ______ % MIN ______ %

COMPRESSOR LOCATION O INDOOR O HEATED O UNHEATED O AT GRADE LEVEL O ELEVATED: ______ FT.

O OUTDOOR O NO ROOF O UNDER ROOF O PARTIAL SIDES O PLATFORM O ON-SHORE

O OFF-SHORE O WEATHER PROTECTION REQ. O TROPICALIZATION REQ.

O WINTERIZATION REQUIRED

UNUSUAL CONDITIONS: O CORROSIVES O DUST O FUMES O OTHER ______

______

ELECTRICAL CLASSIFICATIONS

	HAZARDOUS	NON-HAZARDOUS
MAIN UNIT	O CLASS ______ GROUP ______ DIVISION ______	O
LO CONSOLE	O CLASS ______ GROUP ______ DIVISION ______	O
CW CONSOLE	O CLASS ______ GROUP ______ DIVISION ______	O

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RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

PAGE ______ OF ______
JOB NO. ______ ITEM NO. ______
REVISION ______ DATE ______
BY ______

PART LOAD OPERATING CONDITIONS

CAPACITY CONTROL BY: ○ MFG'S CAP. CONTROL ○ PURCHASERS BY-PASS ○ BOTH ○ OTHER ______
FOR: ○ PART LOAD COND. ○ START-UP ONLY BOTH ○
WITH: ○ AUTO LOADING DELAY INTERLOCK (3.6.2.2) ○ AUTO IMMEDIATE UNLOADING
USING: ○ FIXED VOLUME POCK ○ SUCTION VALVE UNLOADERS: ○ FINGER ○ PLUG OTHER ______
ACTION: ○ DIRECT (AIR-TO-UNLOAD) ○ REVERSE (AIR-TO-LOAD/FAIL SAFE)
NUMBER OF STEPS: ○ ONE ○ THREE ○ FIVE ○ OTHER ______
○ RAIN COVER REQUIRED OVER UNLOADERS

ALL UNLOADING STEPS BASIS MANUFACTURERS CAPACITY SHOWN ON PAGE 1.

INLET AND DISCHARGE PRESSURE ARE ○ AT CYLINDER FLANGES ○ PULSATION SUPPRESSOR FLANGES

○ SERVICE OR ITEM NO.						
⊡ STAGE						
⊡ NORM. OR ALT. CONDITION						
○ PERCENT CAPACITY						
○ WEIGHT FLOW, LBS/HR						
⊡ MMSCFD/SCFM (14.7 PSIA & 60°F)						
☐ POCKETS/VALVES OPERATION*						
☐ POCKET CLEARANCE ADDED %						
☐ TYPE UNLOADERS, PLUG/FINGER						
⊡ INLET TEMPERATURE. °F						
⊡ INLET PRESSURE, PSIA						
⊡ DISCHARGE PRESSURE, PSIA						
☐ DISCHARGE TEMP., ADIABATIC °F						
☐ DISCHARGE TEMP., PREDICTED, °F						
☐ VOLUMETRIC EFF., %HE/%CE	/	/	/	/	/	/
☐ CALC. GAS ROD LOAD, LBS, C**						
☐ CALC. GAS ROD LOAD, LBS, T**						
◇ COMB. ROD LOAD, LBS C (GAS & INERTIA)						
◇ COMB. ROD LOAD, LBS T (GAS & INERTIA)						
◇ ROD REV., DEGREES MIN @ X-HD PIN ***						
☐ BHP/STAGE						
☐ TOTAL BHP @ COMPRESSOR SHAFT						
☐ TOTAL HP INCL. V-BELT & GEAR LOSSES						

* SHOW OPERATION WITH THE FOLLOWING SYMBOLS:

HEAD END = HE OR CRANK END = CE	PLUS	SUCTION VALVE(S) UNLOADED OR FIXED POCKET OPEN OR VARIABLE POCKET OPEN	= S = F = V

EXAMPLE: HE-F/CE-S = HEAD END FIXED POCKET OPEN/CRANK END SUCTION VALVE(S) UNLOADED

C = COMPRESSION T = TENSION * X - HD = CROSSHEAD

☐ MINIMUM PRESSURE REQUIRED TO OPERATE CYLINDER UNLOADING DEVICES, ______ PSIG

CYLINDER UNLOADING MEDIUM: ○ AIR ○ NITROGEN ○ OTHER ______

○ PRESSURE AVAILABLE FOR CYLINDER UNLOADING DEVICES, MAX/MIN ____/____ PSIG

REMARKS, SPECIAL REQUIREMENTS, AND/OR SKETCH

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RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

JOB NO. ____________ ITEM NO. ____________
REVISION ____________ DATE ____________
BY ____________

○ SCOPE OF BASIC SUPPLY

PURCHASER TO FILL IN (□○○) AFTER COMMODITY TO INDICATE: □ BY COMPR. MFR. ○ BY PURCH. ○ BY OTHERS

○ DRIVER (□○○) ○ VARIABLE SPEED SPEED RANGE ________ RPM TO ________ RPM
○ INDUCTION MOTOR ○ SYNCHRONOUS MOTOR ○ STEAM TURBINE ○ ENGINE ○ OTHER ____________
○ API-541 ○ API-546 ○ API-611 ○ API-612
○ OUTBOARD BEARING ○ PROVISION FOR DRY AIR PURGE FOR OUTBOARD BEARING
○ SLIDE BASE FOR DRIVER (□○○) SOLE PLATE FOR DRIVER (□○○)
○ MOTOR STARTING EQUIPMENT (□○○) / DEFINE ____________________________________]
○ GEAR (□○○): ○ BASEPLATE FOR GEAR ○ API-613 ○ API-677
○ COUPLING(S) (□○○): ○ LOW SPD. ○ HI-SPD. ○ QUILL SHAFT ○ KEYLESS DRIVE ○ KEYED DRIVE ○ OTHER ____________
○ API-671
○ V-BELT DRIVE (□○○): ○ SHEAVES & V-BELTS (□○○): ○ STATIC CONDUCTION V-BELTS ○ BANDED V-BELTS
○ DRIVE GUARD(S) (□○○): ○ MANUFACTURER'S STD. ○ NON-SPARKING ○ CALIF CODE ○ API-671 APPENDIX C
○ OTHER ____________________________

○ PULSATION SUPPRESSORS WITH INTERNALS (□○○): ○ INITIAL INLET & FINAL DISCHARGE ○ SUPPORTS (□○○)
○ INTERSTAGE ○ SUPPORTS (□○○)
○ PULSATION SUPPRESSORS WITHOUT INTRNL (□○○): ○ INITIAL INLET & FINAL DISCHARGE ○ SUPPORTS (□○○)
○ INTERSTAGE ○ SUPPORTS (□○○)
○ SUPPRESSOR(S) TO HAVE MOISTURE REMOVAL SECTION: ○ INITIAL INLET ONLY ○ ALL INLET SUPPRESSORS
○ ACOUSTICAL SIMUL. STUDY (□○○) DESIGN APPROACH (Check Only One) ○ 1 ○ 1, W/SIMPLIFIED ANALYSIS OF PIPING SYSTEM
□ DIGITAL □ ANALOG ○ 2, SEE 3.9.2.1 AND APPENDIX M
○ 3, SEE 3.9.2.1 AND APPENDIX M
NOTE: SEE APPENDIX N FOR INFORMATION REQUIRED FOR STUDY
STUDY TO CONSIDER: ALL SPECIFIED LOAD COND., INCL ○ SINGLE ACT., PLUS
○ COMP. OPER. IN PARALLEL ○ ALTERNATE GASES
○ WITH EXISTING COMPRESSORS AND PIPING SYSTEMS
○ STUDY TO BE WITNESSED ○ COMPRESSOR VALVE DYNAMIC RESPONSE
○ VENDOR REVIEW OF PURCHASERS PIPING ARRANGEMENT ○ PULSATION SUPPRESSION DEVICE LOW CYCLE FATIGUE ANALYSIS
○ PIPING SYSTEM FLEXIBILITY

PACKAGED: ○ NO ○ YES (□○○) DEFINE BASIC SCOPE OF PACKAGING IN REMARKS SECTION, PAGE 5
○ SKID ○ SOLEPLATE ○ BASEPLATE ○ BOLTS OR STUDS FOR SOLEPLATE TO FRAME ○ RAILS ○ CHOCK BLOCKS ○ SHIMS
○ SUITABLE FOR COLUMN MOUNTING (UNDER SKID AND/OR BASEPLATE)
○ LEVELING SCREWS ○ NON-SKID DECKING ○ SUB SOLEPLATES
○ DIRECTED GROUTED ○ CEMENTED/MORTAR GROUT ○ EPOXY GROUT; MFG/TYPE ____________ / ____________
○ INTERCOOLER(S) (□○○) ○ SEPARATOR(S) (□○○) ○ AFTERCOOLER(S) (□○○) **INTERCOOLERS:**
○ INTERSTAGE PIP. (□○○): ○ PIPING MATCHMARKED ○ SHOP FITTED ○ MACHINE MOUNTED
○ CONDENSATE SEPARATION & COLLECTION FACILITY SYSTEM PER 3.8.12 ○ OFF MOUNTED
○ INLET STRAINER(S) (□○○): ○ INITIAL INLET ○ SIDESTREAM INLET ○ SPOOL PIECE FOR INLET STRAINERS
○ MANIFOLD PIPING: ○ DRAINS ○ VENTS ○ RELIEF VALVES ○ AIR/GAS SUPPLY **FLANGE FINISH**
○ RELIEF VALVE(S) (□○○): ○ INITIAL INLET ○ INTERSTAGE ○ FINAL DISCHARGE ○ API-618 FLANGE FINISH REF. 3.9.3.15 > 125< 250
○ RUPTURE DISC(S) (□○○): ○ THRU STUDS IN PIPING FLANGES
○ CRANKCASE RAPID PRESSURE RELIEF DEVICE(S) (□○○): ○ FLANGE FINISH PER ANSI 16.5
○ SPECIAL PIPING REQUIREMENTS PER 3.7.1.12.24. (DEFINE IN REMARKS SECTION NEXT PAGE) ○ SPECIAL FINISH ____________

○ INITIAL INLET, ○ INTERSTAGE SUCTION PIPING ARR'D FOR: ○ INSULATION (□○○) ○ HEAT TRACING (□○○)
○ FOR ATMOSPHERIC INLET AIR COMPR. ONLY: ○ INLET AIR FILTER (□○○) ○ INLET FILTER-SILENCER (□○○)
○ PREFERRED TYPE OF CYLINDER COOLING (□○○) ○ FORCED ○ THERMOSYPHON ____________ STAGE CYL'(S)
○ STATIC (STAND-PIPE) ____________ STAGE CYL'(S)
NOTE: MANUFACTURER SHALL RECOMMEND BEST TYPE OF COOLING AFTER FINAL ENGINEERING REVIEW OF ALL OPERATING CONDITIONS
○ CYL. COOLING WATER PIPING (□○○) ○ MATCHMARKED
○ SINGLE INLET/OUTLET MANIFOLD & VALVES ○ SIGHT GLASS(ES)
○ INDIVIDUAL INLET/OUTLET PER CYL. ○ VALVE(S)
○ CLOSED SYS. WITH WATER PUMP, COOLER, SURGE TANK, & PIPING
○ SHOP RUN ○ ARRANGED FOR HEATING JACKET AS WELL AS COOLING

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SCOPE OF BASIC SUPPLY (Cont)

○ SEPARATE COOLING CONSOLE (☐○○): ○ ONE FOR EA. UNIT ○ ONE COMMON TO ALL UNITS ○ DUAL PUMPS (AUX. & MAIN)
○ ARRANGED FOR HEATING JACKET WATER AS WELL AS COOLING

FRAME LUBE OIL SYSTEM (☐○○): ○ AUX PUMP ○ DUAL FILTERS WITH TRANSFER VALVE ○ SHOP RUN
○ CONTINUOUS FLOW IN SENSING LINE TO PRESSURE SWITCHES

○ SEPARATE LUBE OIL CONSOLE (☐○○): ○ EXTENDED TO MOTOR OUTBOARD BEARING ○ SHOP RUN
API-614 APPLIES (REFER TO NOTE OF 2.12.2) ○ NO ○ YES
NOTE: PIPING BETWEEN ALL CONSOLES AND COMPRESSOR UNIT BY PURCHASER

○ CAPACITY CONTROL (☐○○) ○ SEE DATA SHEET PAGE 3 FOR DETAILS ○ IN INSTRUMENT & CONTROL PANEL
○ SEPARATE MACHINE MOUNTED PANEL ○ SEPARATE FREE STANDING PANEL
○ PNEUMATIC ○ ELECTRIC ○ ELECTRONIC ○ HYDRAULIC
○ PROGRAMMABLE CONTROLLER

○ INSTRUMENT & CONTROL PANEL (☐○○): ○ ONE FOR EACH UNIT ○ ONE COMMON TO ALL UNITS
○ MACHINE MOUNTED ○ FREE STANDING (OFF UNIT)

SEE INSTRUMENTATION DATA SHEETS FOR DETAILS OF PANEL, ADDITIONAL REMARKS, AND INSTRUMENTATION

NOTE: ALL TUBING, WIRING, & CONNECTIONS BETWEEN OFF-UNIT FREE STANDING PANELS AND COMPRESSOR UNIT BY PURCHASER

○ HEATERS (☐○○): ○ FRAME LUBE OIL ○ CYL. LUBRICATORS ○ COOLING WATER ○ DRIVER(S) ○ GEAR OIL
○ ELECTRIC ○ STEAM

○ BARRING DEVICE (☐○○): ○ MANUAL ○ PNEUMATIC ○ ELECTRIC ○ FLYWHEEL LOCKING DEVICE (☐○○)
○ ROD PRESSURE PACKING COOLING SYSTEM (☐○○): ○ SEPARATE CONSOLE ○ FILTERS
○ SPECIAL CORROSION PROTECTION: ○ NO ○ YES ○ MFR'S STANDARD ○ OTHER ____________
○ HYDRAULIC TENSIONING TOOLS ○ NO ○ YES
○ MECHANICAL RUN TEST: ○ NO ○ YES ○ MFG'S STANDARD ○ OTHER ____________
○ COMPLETE SHOP RUN TEST OF ALL MACHINE MOUNTED EQUIPMENT, PIPING, & APPURTENANCES

PAINTING: ○ MANUFACTURER'S STANDARD ○ SPECIAL ____________
NAMEPLATES: ○ U.S. CUSTOMARY UNITS ○ SI UNITS
SHIPMENT: ○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED (☐○○)
○ STANDARD 6 MONTH STORAGE PREPARATION (☐○○), PER SPEC ____________
○ OUTDOOR STORAGE FOR OVER 6 MONTHS (☐○○), PER SPEC ____________
○ INITIAL INSTALLATION AND OPERATING TEMP ALIGNMENT CHECK AT JOBSITE BY VENDOR REPRESENTATIVE

○ COMPRESSOR MANUFACTURER'S USER'S LIST FOR SIMILAR SERVICE
○ PERFORMANCE DATA REQUIRED PER 5.3.3: ○ BHP VS. SUCTION PRESSURE CURVES
○ ROD LOAD/GAS LOAD CHARTS
○ VALVE FAILURE DATA CHARTED
○ SPEED/TORQUE CURVE DATA
○ BHP VS CAPACITY PERFORMANCE CURVES OR TABLES REQUIRED FOR UNLOADING STEPS AND/OR VARIABLE SUCTION/DISCHARGE PRESSURES

REMARKS/SPECIAL REQUIREMENTS: ____________

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UTILITY CONDITIONS

ELECTRICAL POWER: AC VOLTS / PHASE / HERTZ DC VOLTS AC VOLTS / PHASE / HERTZ DC VOLTS
○ MAIN DRIVER ____ / ____ / ____ / ____ INSTRUMENT ____ / ____ / ____ / ____
○ AUXILIARY MOTORS ____ / ____ / ____ / ____ ALARM & SHUTDOWN ____ / ____ / ____ / ____
○ HEATERS ____ / ____ / ____ / ____ ____ ____ / ____ / ____ / ____

INSTRUMENT AIR: NORMAL PRESSURE ____ PSIG MAX/MIN ____ / ____ PSIG

STEAM FOR: DRIVERS

INLET: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F
EXHAUST: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F

HEATERS

INLET: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F
EXHAUST: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F

COOLING WATER FOR: COMPRESSOR CYLINDERS

TYPE WATER ____
SUPPLY: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F
RETURN: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F

COOLERS

TYPE WATER ____
SUPPLY: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F
RETURN: PRESS ____ PSIG MAX/MIN ____ / ____ PSIG
(NORMAL) TEMP ____ °F MAX/MIN ____ / ____ °F

COOLING FOR ROD PACKING:
TYPE FLUID ____ SUPPLY PRESS ____ PSIG @ ____ °F RETURN ____ PSIG @ ____ °F

FUEL GAS: NORMAL PRESSURE ____ PSIG MAX/MIN ____ / ____ PSIG LHV ____ BTU/FT³
COMPOSITION ____

REMARKS/SPECIAL REQUIREMENTS:

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1	☐ CYLINDER DATA AT FULL LOAD CONDITION						
2	SERVICE ITEM NO.						
3	STAGE						
4	INLET PRESSURE, PSIA } @ CYLINDER FLANGES						
5	DISCHARGE PRESSURE, PSIA } @ CYLINDER FLANGES						
6	CYLINDERS PER STAGE						
7	SINGLE OR DOUBLE ACTING (SA OR DA)						
8	BORE, INCHES						
9	STROKE, INCHES						
10	RPM: RATED/MAX ALLOW	/					
11	PISTON SPEED, FT/MIN: RATED/MAX ALLOW	/					
12	CYLINDER LINER, YES/NO						
13	LINER NOMINAL THICKNESS, INCHES						
14	PISTON DISPLACEMENT, CFM						
15	CYLINDER DESIGN CLEARANCE, % AVERAGE						
16	VOLUMETRIC EFFICIENCY, % AVERAGE						
17	VALVES, INLET/DISCHARGE, QTY PER CYL.	/	/	/	/	/	/
18	TYPE OF VALVES						
19	VALVE LIFT, INLET/DISCHARGE, INCHES	/	/	/	/	/	/
20	VALVE VELOCITY, API 4TH EDITION, FT/MIN						
21	SUCTION VALVE(S)						
22	DISCHARGE VALVE(S)						
23	ROD DIAMETER, INCHES						
24	MAX ALLOW. COMBINED ROD LOADING, LBS, C *						
25	MAX ALLOW. COMBINED ROD LOADING, LBS, T *						
26	CALCULATED GAS ROD LOAD, LBS, C *						
27	CALCULATED GAS ROD LOAD, LBS, T *						
28	COMBINED ROD LOAD (GAS+INERTIA), LBS, C *						
29	COMBINED ROD LOAD (GAS+INERTIA), LBS, T *						
30	ROD REV., DEGREES MIN @ X-HD PIN **						
31	RECIP WT. (PISTON, ROD, X-HD & NUTS), LBS **						
32	MAX ALLOW, WORKING PRESSURE, PSIG						
33	MAX ALLOW, WORKING TEMPERATURE, °F						
34	HYDROSATIC TEST PRESSURE, PSIG						
35	HELIUM TEST PRESSURE, PSIG						
36	INLET FLANGE SIZE/RATING	/	/	/	/	/	/
37	FACING						
38	DISCHARGE FLANGE SIZE/RATING	/	/	/	/	/	/
39	FACING						
40	DISCHARGE RELIEF VALVE SETTING BASED ON DATA FOR INLET PRESSURES GIVEN ABOVE:						
41	RECOMMENDED SETTING, PSIG						
42	GAS ROD LOAD, LBS, C *						
43	GAS ROD LOAD, LBS, T *						
44	COMBINED ROD LOAD, LBS, C *						
45	COMBINED ROD LOAD, LBS, T *						
46	ROD REVERSAL, DEGREE MIN. @ X-HD PIN **						
47	NOTE: CALCULATED AT INLET PRESSURES GIVEN ABOVE & RECOMMENDED PSV SETTING						
48							
49	○ SETTLE-OUT GAS PRESSURE (DATA REQUIRED FOR STARTING)						
50	*C = COMPRESSION *T = TENSION	** X-HD = CROSSHEAD					
51							

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1	◘ **CONSTRUCTION FEATURES**						
2	SERVICE ITEM NO.						
3	STAGE						
4	CYLINDER SIZE (BORE DIA), INCHES						
5	ROD RUN-OUT: NORMAL COLD VERTICAL (per appendix C)						
6	**MATERIALS OF CONSTRUCTION**						
7	CYLINDER(S)						
8	CYLINDER LINER(S)						
9	PISTON(S)						
10	PISTON RINGS						
11	WEAR BANDS ○ REQUIRED						
12	PISTON ROD(S): MATERIAL/YIELD, PSI	/	/	/	/	/	/
13	THREAD ROOT STRESS @ MACRL * @X-HD END						
14	PISTON ROD HARDNESS, BASE MATERIAL, Rc						
15	PISTON ROD COATING ⊗ REQUIRED						
16	COATING HARDNESS, Rc						
17	VALVE SEATS/SEAT PLATE	/	/	/	/	/	/
18	VALVE SEAT MIN HARDNESS, Rc						
19	VALVE GUARDS (STOPS)						
20	VALVE DISCS						
21	VALVE SPRINGS						
22	ROD PRESSURE PACKING RINGS						
23	ROD PRESSURE PACKING CASE						
24	ROD PRESSURE PACKING SPRINGS						
25	SEAL/BUFFER PACKING, DISTANCE PIECE						
26	SEAL/BUFFER PACKING, INTERMEDIATE						
27	WIPER PACKING RINGS						
28	MAIN JOURNAL BEARINGS, CRANKSHAFT						
29	CONNECTING ROD BEARING, CRANKPIN						
30	CONNECTING ROD BUSHING, X-HD END						
31	CROSSHEAD (X-HD) PIN BUSHING						
32	CROSSHEAD PIN						
33	CROSSHEAD						
34	CROSSHEAD SHOES						
35	CYLINDER INDICATOR VALVES (✓)						
36	INDICATOR CONNECTIONS ABOVE 5000 PSI						
37	FLUOROCARBON SPRAYED CYLINDER (✓)						
38	INSTRUMENTATION IN (✓) COLD SIDE						
39	CONTACT W/PROCESS GAS (✓) HOT SIDE						
40	*MAXIMUM ALLOWABLE COMBINED ROD LOAD	USE (✓) IN APPROPRIATE COLUMN WHERE APPLICABLE					

41	◘ COMPRESSOR CYLINDER ROD PACKING	DISTANCE PIECES: ○ TYPE A ○ TYPE B ○ TYPE C ○ TYPE D
42	○ FULL FLOATING PACKING	Ref: Appendix G, Fig. G-3
43	○ VENTED TO: ○ FLARE @ ____ PSIG ○ ATMOSPHERE	COVERS: ○ SOLID METAL ○ SCREEN ○ LOUVERED
44	○ SUCTION PRESSURE @ ______ PSIG	CYLINDER COMPARTMENT: (Outboard Distance Piece) ○ VENTED TO ______ PSIG
45	○ FORCED LUBRICATED ○ NON-LUBE ○ TFE	○ PURGED AT ______ PSIG
46	◘ WATER COOLED, ______ STAGE(S), ______ GPM REQ'D	○ PRESSURIZED TO ______ PSIG
47	◘ OIL COOLED, ______ STAGE(S), ______ GPM REQ'D	○ WITH RELIEF VALVE
48	○ WATER FILTER PROV. FUTURE WATER/OIL COOLING	FRAME COMPARTMENT: (Inboard Distance Piece) ○ VENTED TO ______ PSIG
49	○ VENT/BUFFER GAS SEAL PACKING ARR. (REF. APPENDIX I FIG I-1)	○ PURGED AT ______ PSIG
50	○ CONSTANT OR ○ VARIABLE DISPOSAL SYSTEM	○ PRESSURIZED TO ______ PSIG
51	○ BUFFER GAS PRESSURE, ______ PSIG	○ WITH RELIEF VALVE
52	○ SPLASH GUARDS FOR WIPER PACKING	☐ DISTANCE PIECE MAWP ______ PSIG

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☒ CONSTRUCTION FEATURES (CONTINUED)

O FABRICATED CYLINDER, HEADS, & CONNECTION SKETCHES FOR DESIGN REVIEW BY PURCHASER. (2.14.5.2.8)

☒ COUPLING(S)

	O LOW SPEED Between Compressor & Driver or Gear	O HIGH-SPEED Between Driver & Gear
◇ BY MANUFACTURER	______	______
◇ MODEL	______	______
◇ TYPE	______	______
	______	______

API-671 APPLIES O YES O NO

O INSPECTION AND SHOP TESTS (REF. 4.1.3)

	REQ'D	WITN.	OBSER.
* SHOP INSPECTION	O	O	O
ACTUAL RUNNING CLEARANCES AND RECORDS	O	O	O
MFG STANDARD SHOP TESTS	⊗	O	O
CYLINDER HYDROSTATIC TEST	⊗	O	O
CYLINDER PNEUMATIC TEST	⊗	O	O
CYLINDER HELIUM LEAK TEST	O	O	O
CYL JACKET WATER HYDRO TEST	⊗	O	O
*MECHANICAL RUN TEST (4 HR)	O	O	O
BAR-OVER TO CHECK ROD RUNOUT	⊗	O	O
*LUBE OIL CONSOLE RUN/TEST (4 HR)	O	O	O
*COOLING H_2O CONSOLE RUN/TEST	O	O	O
RADIOGRAPHY BUTT WELDS	O	O	O
O GAS O OIL O FAB CYLS			
MAG PARTICLE/LIQUID PENETRANT OF WELDS	O	O	O
SPECIFY ADDITIONAL REQUIREMENTS (4.2.1.3)			
______	O	O	O
QC OF INACCESSIBLE WELDS (2.14.5.2.4)	O		
SHOP FIT-UP OF PULSATION SUPPL DEVICES & ALL ASSOCIATED GAS PIPING	O	O	O
*CLEANLINESS OF EQUIP., PIPING, & APPURTENANCES	O	O	O
*HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES	O	O	O
*NOTIFICATION TO PURCHASER OF ANY REPAIRS TO MAJOR COMPONENTS	O		
______	O	O	O
______	O	O	O

*SPECIFIC REQUIREMENTS TO BE DEFINED, FOR EXAMPLE, DISMANTLING, AUX EQUIPMENT OPERATIONAL & RUN TESTS.

APPENDIX K COMPLIANCE: O VENDOR
O PURCHASER

O BUFFER GAS PACKING ARR. Ref: Appendix I Figures I-1, I-2 & I-3

O OIL WIPER PACKING PURGE

O INTERMEDIATE PARTITION PURGE

INERT BUFFER/PURGE GAS: O N_2 O OTHER ______

O VENT, DRAIN, PURGE PIPING BY MFG'R O NO O YES

☐ V-BELT DRIVE

	DRIVEN SHEAVE (Compressor Shaft)	DRIVE SHAFT (Driver shaft)
RPM (EXPECTED)	______	______
PITCH DIA. (Inches)	______	______
◇ QTY & GROOVE X-SEC	______	______
POWER TRANSMITTED	______	______ Incl. Belt Losses

DRIVER NAMEPLATE HP RATING ______

◇ CENTER DISTANCE (INCHES) ______

◇ QTY, TYPE, ______ X-SEC., & LENGTH BELTS ______

◇ BELT SERVICE FACTOR (RELATIVE TO DRIVER NAMEPLATE HP RATING ______

☒ CYLINDER LUBRICATION

O NON-LUBE ______ STAGE(S)/SERVICE

O LUBRICATED ______ STAGE(S)/SERVICE

TYPE OF LUBE OIL O SYNTHETIC ______
O HYDROCARBON ______

LUBRICATOR DRIVE BY: ☐ COMP. CRANKSHAFT, DIRECT
☐ CHAIN, FROM CRANKSHAFT
☒ ELECTRIC MOTOR
☒ OTHER ______

◇ LUBRICATOR MFR ______

◇ MODEL ______

TYPE LUBRICATOR: (2.13) O SINGLE PLUNGER PER POINT
O DIVIDER BLOCKS

◈ COMPARTMENT, TOTAL QTY ______

◈ PLUNGERS (PUMPS), TOTAL QTY ______

◈ SPARE PLUNGERS, QTY ______

◈ SPARE COMPARTMENT W/OUT PLUNGERS ______

O HEATERS: O ELECTRIC W/THERMOSTAT O STEAM

☐ ESTIMATED WEIGHTS AND NOMINAL DIMENSIONS

☐ TOTAL COMPR. WT, LESS DRIVER & GEAR ______ LBS

◇ WT, OF COMPLETE UNIT, (LESS CONSOLES) ______ LBS

◇ MAXIMUM ERECTION WEIGHT ______ LBS

◇ MAXIMUM MAINTENANCE WEIGHT ______ LBS

◇ DRIVER WEIGHT/GEAR WEIGHT ______/______ LBS

◇ LUBE OIL/COOLING H_2O CONSOLE ______/______ LBS

◇ FREE STANDING PANEL ______ LBS

SPACE REQUIREMENTS-FEET:	LENGTH	WIDTH	HEIGHT
◇ COMPLETE UNIT	______	______	______
◇ LUBE OIL CONSOLE	______	______	______
◇ COOLING H_2O CONSOLE	______	______	______
◇ FREE STANDING PANEL	______	______	______

☐ PISTON ROD REMOVAL DIST. ______

OTHER EQUIPMENT SHIPPED LOOSE (DEFINE)

◇ PULSATION SUPPRESSOR, WEIGHT ______ LBS

◇ PIPING ______ LBS

◇ INTERSTAGE EQUIPMENT ______ LBS

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☐ UTILITY CONSUMPTION

ELECTRIC MOTORS

For Induction Motors See Note of 3.1.2.5 and Motor Data sheet	NAMEPLATE HP	LOCKED ROTOR AMPS	FULL LOAD STEADY STATE AMPS	MAIN DRIVER NON-STEADY STATE AMPS AT COMPRESSOR RATED HORSEPOWER (Induction Motors Only)
◇ MAIN DRIVER				______ AMPS
◇ MAIN LUBE OIL PUMP				@ COMPRESSOR RATED
◇ AUX LUBE OIL PUMP				HP OF ______
◇ MAIN COOLING WATER PUMP				@ CURRENT PULSATIONS
◇ AUX COOLING WATER PUMP				OF ______ %
◇ ROD PACKING COOLING PUMP				
◇ CYLINDER LUBRICATOR				

ELECTRIC HEATERS

	WATTS	VOLTS	HERTZ
◇ FRAME OIL HEATER(S)			
◇ COOLING WATER HEATER(S)			
◇ CYL. LUBRICATOR HEATER(S)			

STEAM

	FLOW		PRESSURE		TEMPERATURE		BACK PRESSURE	
◇ MAIN DRIVER		LBS/HR @		PSIG		°FTT TO		PSIG
◇ FRAME OIL HEATER(S)		LBS/HR @		PSIG		°FTT TO		PSIG
◇ CYL. LUB. HEATER(S)		LBS/HR @		PSIG		°FTT TO		PSIG
		LBS/HR @		PSIG		°FTT TO		PSIG
		LBS/HR @		PSIG		°FTT TO		PSIG

COOLING WATER REQUIREMENTS

	FLOW GPM	INLET TEMP °F	OUTLET TEMP °F	INLET PRESS PSIG	OUTLET PRESS PSIG	MAX PRESS PSIG
☐ CYLINDER JACKETS						
◇ INTERCOOLER(S)						
◇ AFTERCOOLER						
◇ FRAME LUBE OIL COOLER						
◇ ROD PRESSURE PACKING*						
◇ TOTAL QUANTITY, GPM						

REMARKS/SPECIAL REQUIREMENTS:

* ROD PACKING COOLANT MAY BE OTHER THAN WATER

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⊡ FRAME LUBE OIL SYSTEM

⊡ **BASIC LUBE OIL SYSTEM FOR FRAME:** ⊡ SPLASH ⊡ PRESSURE (FORCED) ○ HEATERS REQUIRED:
REF: TYPE MAIN BEARINGS: ⊡ TAPERED ROLLER ⊡ PRECISION SLEEVE ○ ELEC. W/ THERMOSTAT(S) ○ STEAM
⊡ **PRESSURE SYSTEM:** ○ MAIN OIL PUMP DRIVEN BY: ○ COMP. CRANKSHAFT ○ ELEC. MOTOR ○ OTHER ____________
☐ PSV FOR MAIN PUMP EXTERNAL TO CRANKCASE
○ AUX OIL PUMP DRIVEN BY: ○ ELEC. MOTOR ○ OTHER ____________
☐ HAND OPERATED PRE-LUBE PUMP FOR STARTING ○ OPERATIONAL TEST & 4 HOUR MECH RUN TEST
○ API-614 LUBE SYSTEM: ○ NO ○ YES (See Note of 2.12.2) ○ CHECK VALVE ON MAIN PUMP (FIG G-5)
○ CONTINUOUS FLOW THROUGH OF OIL (3.7.2.7)
○ **SEP. CONSOLE FOR PRESS. LUBE SYS:** ○ ONE CONSOLE FOR EA. COMP. ○ ONE CONSOLE FOR ______ COMPRESSORS
NOTE: Instrumentation to be listed on Instrumentation Data Sheets ○ CONSOLE TO BE OF DECK PLATE TYPE CONSTRUCTION SUITABLE FOR MULTI-POINT SUPPORT AND GROUTING WITH GROUT & VENT HOLES.
○ ELECTRICAL CLASSIFICATION: CLASS ________, GROUP ________, DIV ________ ○ NON-HAZARDOUS

☐ **BASIC SYS. REQ'MTS (NORM. OIL FLOWS & VOLUMES)**

	FLOW GPM	PRESSURE PSIG	VISCOSITY SSU @ 100°F	VISCOSITY SSU @ 210°F	SUMP VOLUME GALLONS
☐ LUBE OIL					
☐ COMPRESSOR FRAME					
◇ DRIVER					
◇ GEAR					

☐ SYSTEM PRESSURES: ☐ DESIGN ________ PSIG ☐ HYDROTEST ________ PSIG
☐ PRESSURE CONTROL VALVE SETTING ______ PSIG ☐ PUMP RELIEF VALVE(S) SET ______ PSIG

○ **PIPING MATERIALS:**

	CARBON STEEL	STAINLESS STEEL WITH SS FLANGES	STAINLESS STEEL WITH CARBON STEEL FLANGES
○ UPSTREAM OF PUMPS & FILTERS	○	○	○
○ DOWNSTREAM OF FILTERS	○	○	○
○ ____________	○	○	○
○ ____________	○	○	○

☐ PUMPS (Gear or Screw Type Only)	◇ RATED FLOW GPM	◇ PRESSURE PSIG	◇ COLD START REQ'D BHP	◇ DRIVER HP	◇ SPEED RPM	COUPLING REQ'D	MECH. SEAL REQ'D
MAIN						○	○
AUXILIARY						○	○

☐ PUMP CASING MATERIAL (2.12.3.1): MAIN PUMP ____________ AUX PUMP ____________
○ GUARD(S) REQ. FOR COUPLING(S): ○ MAIN PUMP ○ AUX PUMP ○ GUARD TYPE OR CODE ____________
○ AUXILIARY PUMP CONTROL: ○ MANUAL ○ AUTOMATIC ○ ON-OFF-AUTO SEL. SWITCH: ○ BY PURCH. ○ BY MFR.
○ WIRING TO TERMINAL BOX: ○ BY PURCH ○ BY MFR.
○ SWITCHES ○ RTD'S/THERMOCOUPLES

○ **COOLERS:** ○ SHELL & TUBE ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ MFG'S STD. ○ TEMA C ○ TEMA R (API-660 Data Shts Attached)
○ REMOVABLE BUNDLE ○ WATER COOLED ○ AIR COOLED W/AUTO TEMP CONTROL (API-661 Data Shts Attached)
○ W/BYPASS & TEMP CONTROL VALVE: ○ MANUAL ○ AUTO ○ SEE SEPARATE HEAT EXCHANGER DATA SHEET FOR DETAILS, SPECIFY % GLYCOL ON COOLING WATER SIDE

⊡ **FILTER(S)** ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ ASME CODE DESIGN ○ ASME CODE STAMPED
☐ DESIGN PRESSURE, ______ PSIG ☐ ΔP CLEAN, ______ PSI ☐ ΔP COLLAPSE, ______ PSI
☐ MICRON RATING, ________ ☐ CARTRIDGE MATERIAL, ________ ◇ CARTRIDGE P/N ________
☐ BONNET MATERIAL, ________ ☐ CASING MATERIAL, ________ ○ FURN. SPARE CARTR., QTY ________

☐ SYS. COMPONENT SUPP.	MANUFACTURER	MODEL		MANUFACTURER	MODEL
◇ MAIN PUMP			◇ OIL COOLER(S)		
◇ AUXILIARY PUMP			◇ TRANSFER VALVE(S)		
◇ MECHANICAL SEALS			◇ PUMP COUPLING(S)		
◇ ELECTRIC MOTORS			◇ SUCTION STRAINER(S)		
◇ STEAM TURBINES			◇ CHECK VALVE(S)		
◇ OIL FILTER(S)			◇ ____________		

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RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

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☐ COOLING WATER SYSTEM

○ **BASIC COOLING SYS. FOR:** ○ COMPRESSOR CYL.(S) ○ INTERCOOLER(S) ○ AFTERCOOLER ○ OIL COOLER(S)
○ HEATERS REQ.'D FOR PRE-HEATING: ○ ELEC. W/THERMOSTAT(S) ○ STEAM

○ **PRESSURE FORCED CIRCULATING SYS:** ○ OPEN, PIPING BY: ○ PURCH ○ MFR. ○ CLOSED, PIPING BY MANUFACTURER
MAIN WATER PUMP DRIVEN BY: ○ ELEC. MOTOR ○ STEAM TURBINE ○ OTHER ______
AUX WATER PUMP DRIVEN BY: ○ ELEC. MOTOR ○ STEAM TURBINE ○ OTHER ______

○ **SEP. CONSOLE FOR COOLING WATER SYS:** ○ ONE CONSOLE FOR EA. COMP. ○ ONE CONSOLE FOR ____ COMPRESSORS
NOTE: Instrumentation to be listed on Instrumentation Data Sheets
○ CONSOLE TO BE OF DECK PLATE TYPE CONSTRUCTION SUITABLE FOR MULTI-POINT SUPPORT AND GROUTING WITH GROUT & VENT HOLES.
○ ELECTRICAL CLASSIFICATION: CLASS ______, GROUP ______, DIV ______ ○ NON-HAZARDOUS

☐ **BASIC SYS. REQ'MTS (NORM. COOLING WATER FLOW DATA)** COOLING WATER TO BE ____ % ETHYLENE GLYCOL

	FORCED COOL'G	THERMO SYPHON	STAND PIPE	FLOW GPM	PRESSURE PSIG	INLET TEMP °F	OUTLET TEMP °F	SIGHT FLOW INDICATORS
CYLINDER(S), ____ STAGE	○	○	○	______	______	______	______	○
CYLINDER(S), ____ STAGE	○	○	○	______	______	______	______	○
CYLINDER(S), ____ STAGE	○	○	○	______	______	______	______	○
CYLINDER(S), ____ STAGE	○	○	○	______	______	______	______	○
CYLINDER(S), ____ STAGE	○	○	○	______	______	______	______	○
CYLINDER(S), ____ STAGE	○	○	○	______	______	______	______	○
PISTON ROD PACK'G TOTAL	○			______	______	______	______	○
INTERCOOLER(S) TOTAL	○			______	______	______	______	○
AFTERCOLLER	○			______	______	______	______	○
OIL COOLER(S)	○			______	______	______	______	○
______	○			______	______	______	______	○
TOTAL FLOW				______				

☐ **SYS. PRESSURES:** ☐ DESIGN, ______ PSIG ☐ HYDROTEST, ______ PSIG ☐ RELIEF VALVE(S), SETTING ______ PSIG

☐ **WATER RESERVOIR:** ◇ SIZE: ______ FT/IN DIA X ______ FT/IN HT. ◇ CAPACITY ______ GALLONS @Normal Operating Level
◇ RESERVOIR MATERIAL ◇ INTERNAL COATING, TYPE ______
○ LEVEL GAUGE ○ LEVEL SWITCH ○ DRAIN VALVE ○ INSPECTION & CLEAN-OUT OPENINGS

☐ **PUMPS (Centrifugal Only)**

	◇ RATED FLOW GPM	◇ PRESSURE PSIG	◇ REQ'D BHP	◇ DRIVER HP	◇ SPEED RPM	COUPLING REQ'D	MECH. SEAL REQ'D
MAIN	______	______	______	______	______	○	○
AUXILIARY	______	______	______	______	______	○	○

☐ PUMP CASING MATERIAL (Ref. 2.12.3.1): MAIN PUMP ______ AUX PUMP ______
○ GUARD(S) REQ. FOR COUPLING(S): ○ MAIN PUMP ○ AUX PUMP ○ GUARD TYPE OR CODE ______
○ AUXILIARY PUMP CONTROL: ○ MANUAL ○ AUTOMATIC ○ ON-OFF-AUTO SEL. SWITCH: ○ BY PURCH. ○ BY MFR.
○ WIRING TO TERMINAL BOX: ○ BY PURCH ○ BY MFR.

○ **COOLING WATER HEAT EXCH:** ○ SHELL & TUBE ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ TEMA C ○ TEMA R (API-660 Data Shts Attached)
○ AIR COOLED EXCHANGER W/AUTO TEMP CONTROL (API-661 Data Sheets Attached)
○ W/BYPASS & TEMP CONTROL VALVE: ○ MANUAL ○ AUTO ○ LOUVERS FOR AIR EXCH.
○ SEE SEPARATE COOLER DATA SHEET FOR DETAILS; SPECIFY % GLYCOL ON BOTH SIDES OF SHELL & TUBE

SYS. COMPONENT SUPP.	MANUFACTURER	MODEL		MANUFACTURER	MODEL
◇ MAIN PUMP	______	______	◇ TEMP CONTROL VALVE(S)	______	______
◇ AUXILIARY PUMP	______	______	◇ TRANSFER VALVE(S)	______	______
◇ MECHANICAL SEALS	______	______	◇ PUMP COUPLING(S)	______	______
◇ ELECTRIC MOTORS	______	______	◇ ______	______	______
◇ STEAM TURBINES	______	______	◇ ______	______	______
◇ ______	______	______	◇ ______	______	______
◇ ______	______	______	◇ ______	______	______

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RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

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PULSATION SUPPRESSION DEVICES FOR RECIPROCATING COMPRESSORS

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE OF COMRESSION

APPLICABALE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT
FOR/USER ______
SITE/LOCATION ______ AMBIENT TEMPERATURE MIN/MAX ______ / ______ °F
COMPRESSOR SERVICE ______
COMPRESSOR MFG. ______ NUMBER OF COMPRESSORS ______
SUPPRESSOR MFG. ______ MODEL/TYPE ______
NOTE: ○ Ind. Data Comp.'d Purch. □ By Compr/Supp. Mfg. w/Proposal ◇ By Mfg(s) after order ⊡ By Mfg(s) or Purchaser as Applicable

GENERAL INFORMATION APPLICABLE TO ALL SUPPRESSORS

TOTAL NUMBER OF SERVICES AND/OR STAGES ______
TOTAL NUMBER OF COMPRESSOR CYL. ______ TOTAL NUMBER OF CRANKTHROWS ______ STROKE ______ IN. RPM ______
○ ASME CODE STAMP ○ GOVERNMENTAL CODES OF ______ CODE REGULATIONS APPLY
○ OTHER APPLICABLE PRESSURE VESSEL SPEC. OR CODE ______
○ LUBE SERVICE ○ NON-LUBE SERV. ○ NO OIL ALLOWED INTERNALLY DRY TYPE INTERNAL CORROSION COATING ○ YES ○ NO
RADOGRAPHY OF WELDS ○ NONE ○ SPOT ○ 100% ○ IMPACT TEST ○ SPECIAL WELDING REQUIREMENTS
○ SHOP INSPECTION ○ WITNESS HYDROTEST ○ OUTDOOR STORAGE OVER 6 MONTHS ○ SPECIAL PAINT SPEC ______
○ WITNESSED ○ OBSERVED

CYLINDER, GAS, OPERATING, AND SUPPRESSOR DESIGN DATA

	SERVICE ______	STAGE NO. ______
□ COMPRESSOR MANUFACTURER'S RATED CAPACITY	LBS/HR ______ SCFM ______	MMSCFD ______
⊡ LINE SIDE OPERATING PRESSURE	INLET, ______ PSIA	DISCHARGE ______ PSIA
⊡ OPERATING TEMP. WITHIN SUPPRESSORS	INLET, ______ °F	DISCHARGE, ______ °F
○ ALLOWABLE PRESSURE DROP THROUGH SUPPRESSORS	Δ P ______ PSI / ______ %	Δ P ______ PSI / ______ %
	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
○ SUPPRESSOR TAG NUMBER		
○ COMBINATION INLET SUPP SEPARATOR/INTERNALS	○ YES ○ NO / ○ YES ○ NO	/ ○ YES ○ NO
⊡ NO. (QTY) OF INLET & DISCH. SUPP. PER STAGE		
○ ALLOWABLE PEAK-PEAK PULSE @ LINE SIDE NOZZLE	PSI / %	PSI / %
○ ALLOWABLE PEAK-PEAK PULSE @ CYL FLANGE NOZZLE	PSI / %	PSI / %
○ DESIGN FOR FULL VACUUM CAPABILITY	○ YES ○ NO	○ YES ○ NO
○ MIN. REQ'D WORKING PRESSURE & TEMPERATURE NOTE: After design, the actual Mawp & temp are to be determined based on the weakest component and stamped on the vessel, the actual Mawp is to be shown on pg. 14 line 12 and on the U1A Forms.	PSIG. ______ @ ______ °F	PSIG ______ @ ______ °F
○ INITIAL SIZING VOL. PER FORMULA OF 3.9.2.2.2 NOTE: This is a Reference	______ FT³	______ FT³
◇ AS BUILT VOLUME (FT³)	______ FT³	______ FT³

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RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

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PULSATION SUPPRESSION DEVICES FOR RECIPROCATING COMPRESSORS (CONT'D)

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE OF COMRESSION

SERVICE ______
STAGE NO. ______

CONSTRUCTION REQUIREMENTS & DATA	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
○ SUPPRESSOR TAG NUMBER		
○ BASIC MATERIAL REQUIRED, CS, SS, ETC.		
◇ ACTUAL MATERIAL DESIGNATION SHELL/HEAD	/	/
○ SPECIAL HARDNESS LIMITATIONS, Rc ○ YES ○ NO	SHELL & HEADS WELDS	SHELL & HEADS WELDS
▣ CORROSION ALLOWANCE, IN. ○ REQUIRED	IN.	IN.
◇ WALL THICKNESS, IN. SHELL/HEAD	IN. / IN.	IN. / IN.
□ NOM. SHELL DIA X OVERALL LGTH. (INCH/VOL. FT³)	x IN / FT³	x IN / FT³
□ PIPE OR ROLLED PLATE CONSTRUCTION	□ PIPE □ ROLLED PLATE	□ PIPE □ ROLLED PLATE
◇ ACT. MAX. ALLOW. WORKING PRESS. AND TEMPERATURE	PSI @ °F	PSI @ °F
○ MINIMUM DESIGN METAL TEMP (2.14.8.1)	°F	°F
○ INLET SUPPRESSOR TO BE SAME MAWP AS DISCHARGE SUPPRESSOR	○ YES ○ NO	
◇ MAX. EXPECTED PRESSURE DROP(Δ P, PSI / %) LINE PRESS	Δ P PSI / %	Δ P PSI / %
◇ WEIGHT, (LBS EACH)	LBS	LBS
○ INSUL. NUTS & ALLOW. FOR INSULATION REQUIRED (✓)		
◇ EXPECTED P-P PULSE @ LINE SIDE/CYL FLG, % LINE PRESS BASED ON FINAL SUPPRESSOR DESIGN	% / %	% / %
▣ SUPPORTS, TYPE/QUANTITY		
CONNECTION REQUIREMENTS & DATA		
○ LINE SIDE FLANGE, SIZE/RATING/TYPE		
○ COMP CYL FLANGE(S), QTY/SIZE/RATING/FACING/TYPE		
○ FLANGE FINISH, ○ PER 3.9.3.15 > 125 <250 ○ SPECIAL (SPECIFY) ○ PER ANSI 16.5		
○ INSPECTION OPENINGS REQUIRED ○ SPEC. QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING	○ YES ○ NO ○ BLINDED	○ YES ○ NO ○ BLINDED
◇ * QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING		
○ VENT CONNECTIONS REQUIRED ○ SPEC. QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING	○ YES ○ NO	○ YES ○ NO
◇ * QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING		
○ DRAIN CONNECTIONS REQUIRED ○ SPEC. QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING	○ YES ○ NO	○ YES ○ NO
◇ * QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING		
○ PRESSURE CONNECTIONS REQUIRED ○ SPEC. QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING	○ YES ○ NO	○ YES ○ NO
◇ * QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING		
○ TEMPERATURE CONNECTIONS REQUIRED ○ SPEC. QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING ○ CYL NOZZLE ○ MAIN BODY	○ YES ○ NO	○ YES ○ NO
◇ * QTY, SIZE, 6000 LB NPT CPLG./FLG TYPE & RATING		
OTHER DATA AND NOTES		
◇ COMPRESSOR MFG'S SUPP. OUTLINE OR DRAWING NO.		
◇ SUPP. MFG'S OUTLINE OR DRAWING NO.		
NOTES* = AS BUILT		

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☐ **INSTRUMENTATION**

PURCHASER TO FILL IN (□○○) AFTER COMMODITY TO INDICATE: □ BY COMPR. MFG ○ BY PURCHASER ○ BY OTHERS

INSTRUMENT & CONTROL PANEL (□○○):
○ ONE FOR EA. UNIT ○ ONE COMMON TO ALL UNITS
○ MACHINE MT'ED ○ FREE STANDING (OFF UNIT) ○ LOCAL ○ REMOTE ○ OUTDOORS
○ PNEUMATIC ○ ELEC. ○ ELECTRONIC ○ HYDRAULIC ○ PROGRAMMABLE CONTL'R
○ NEMA 7 CLASS ______, GROUP ______, DIVISION ______ ○ INTRINSINCALLY SAFE
○ I/S BARRIERS (□○○)
○ NEMA 4, WATERTIGHT & DUSTTIGHT ○ PURGED TO NFPA 496 TYPE ○ X ○ Y ○ Z
○ OTHER NEMA ______ LOW PURGE PRESS. ○ ALARM ○ SHUTDOWN
○ VIB. ISOLATORS ○ STRIP HEATERS ○ PURGE CONN. ○ EXTRA CUTOUTS
○ ANNUNCIATOR W/FIRST-OUT INDICATION LOCATED ON CONTROL PANEL
○ PURCHASER'S CONN. BROUGHT OUT TO TERMINAL BOX BY VENDOR

ADDITIONAL PANEL REMARKS:

○ INSTRUMENTATION SUITABLE FOR: ○ INDOORS ○ OUTDOORS ○ OTHER ______

○ PREFERRED INSTRUMENT SUPPLIERS, (TO BE COMPLETED BY PURCHASER), OTHERWISE MFR'S STANDARD APPLIES

PRESSURE GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
TEMPERATURE GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
LIQUID LEVEL GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
DIFF. PRESSURE GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
PRESS. TRANSMITTERS	MFR ______	SIZE & TYPE ______	MTL ______
LIQUID LEV. TRANSMITTER	MFR ______	SIZE & TYPE ______	MTL ______
PRESSURE SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
TEMPERATURE SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
LIQUID LEVEL SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
DIFF. PRESSURE SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
CONTROL VALVES	MFR ______	SIZE & TYPE ______	MTL ______
PRESSURE SAFETY VALVES	MFR ______	SIZE & TYPE ______	MTL ______
SIGHT FLOW INDICATORS	MFR ______	SIZE & TYPE ______	MTL ______
VIBRATION MONITORS & EQUIP.	MFR ______	SIZE & TYPE ______	MTL ______
THERMOCOUPLES	MFR ______	SIZE & TYPE ______	MTL ______
RTD'S	MFR ______	SIZE & TYPE ______	MTL ______
SOLENOID VALVES	MFR ______	SIZE & TYPE ______	MTL ______
ANNUNCIATOR	MFR ______	MODEL & (QTY SPARE POINTS) ______ (____)	
PROGRAMMABLE CONTROLLER	MFR ______	SIZE & TYPE ______	MTL ______
______	MFR ______	SIZE & TYPE ______	MTL ______
______	MFR ______	SIZE & TYPE ______	MTL ______

○ PRESSURE GAUGE REQUIREMENTS ○ LIQUID FILLED PRESSURE GAUGES: ○ YES ○ NO

FUNCTION	LOCALLY MOUNTED	PANEL MOUNTED		LOCALLY MOUNTED	PANEL MOUNTED
LUBE OIL MAIN PUMP DISCHARGE	(□○○)	(□○○)	PROCESS GAS: INLET PRESS.		
LUBE OIL AUX PUMP DISCHARGE	(□○○)	(□○○)	@ EA. STAGE	(□○○)	(□○○)
LUBE OIL PRESS. AT FRAME HEADER	(□○○)	(□○○)	DISCH. PRESS.		
LUBE OIL FILTER Δ P	(□○○)	(□○○)	@ EA. STAGE	(□○○)	(□○○)
COOLING WATER INLET HEADER	(□○○)	(□○○)	______	(□○○)	(□○○)
______	(□○○)	(□○○)	______	(□○○)	(□○○)
______	(□○○)	(□○○)	______	(□○○)	(□○○)

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INSTRUMENTATION (CONT'D)

TEMPERATURE MEASUREMENT REQUIREMENTS

FUNCTION	LOCALLY MNT'D	PANEL MNT'D	GAUGE W/ CAPILLARY	THERMO-COUPLE SYS	RTD SYS	I/S SYS
LUBE OIL ○ INLET TO ○ OUT OF FRAME	(□○○)	(□○○)	○	○	○	○
LUBE OIL ○ INLET TO ○ OUT OF COOLER	(□○○)	(□○○)	○	○	○	○
MAIN JRNL BEARINGS (THERMOCOUPLES OR RTD'S ONLY)	(□○○)	(□○○)	○	○	○	○
MOTOR BEARING(S) (THERMOCOUPLES OR RTD'S ONLY)	(□○○)	(□○○)	○	○	○	○
COOLING WATER HEADER: ○ INLET ○ OUTLET	(□○○)	(□○○)	○	○	○	○
CYL. COOLING WATER: ○ INLET ○ OUTLET ○ EACH CYL	(□○○)	(□○○)	○	○	○	○
PROCESS GAS: ○ INLET ○ DISCHARGE ○ EACH CYL	(□○○)	(□○○)	○	○	○	○
INTERCOOLER(S): ○ INLET ○ GAS ○ WATER	(□○○)	(□○○)	○	○	○	○
○ INLET ○ GAS ○ WATER	(□○○)	(□○○)	○	○	○	○
AFTERCOOLER: ○ INLET ○ GAS ○ WATER	(□○○)	(□○○)	○	○	○	○
○ INLET ○ GAS ○ WATER	(□○○)	(□○○)	○	○	○	○
COOLING WATER ○ INLET ○ OUTLET/COOLED PKG CASE(S)	(□○○)	(□○○)	○	○	○	○
PRESS. PKG CASE, CYL PIST ROD (THERMOCOUPLES OR RTD' ONLY)	(□○○)	(□○○)		○	○	○
COMPRESSOR VALVES ○ SUCT ○ DISCH TC'S OR RTD'S ONLY)	(□○○)	(□○○)	○	○	○	○
______	(□○○)	(□○○)	○	○	○	○
______	(□○○)	(□○○)	○	○	○	○

ALARM & SHUTDOWN SWITCH REQ'MTS NOTE: ALARM & SHUTDOWN SWITCHES SHALL BE INDIVIDUALLY SEPARATE

			ANNUNCIATION POINTS				
			ALARM		SHUTDOWN		TOTAL NO. OF POINTS
FUNCTION	ALARM	SHUT-DOWN	IN PNL BY MFR	IN CTL ROOM PNL OTHERS	IN PNL BY MFR	IN CTL ROOM PNL OTHERS	
LOW LUBE OIL PRESS. @ BEARING HEADER	(□○○)	(□○○)	○	○	○	○	______
HIGH LUBE OIL Δ P ACROSS FILTER	(□○○)	(□○○)	○	○	○	○	______
LOW LUBE OIL LEVEL, FRAME	(□○○)	(□○○)	○	○	○	○	______
AUX LUBE OIL PUMP, FAIL TO START	(□○○)	(□○○)	○	○	○	○	______
CYL LUBE SYSTEM PROTECTION	(□○○)	(□○○)	○	○	○	○	______
COMPR. VIBRATION, SHUTDOWN ONLY		(□○○)			○	○	______
VIBRATION, W/ CONTINUOUS MONITORING	(□○○)	(□○○)	○	○	○	○	______
ROD DROP DETECTOR, CONTACT TYPE (1/CYL)	(□○○)	(□○○)	○	○	○	○	______
ROD DROP PROXIMITY PROBES (I/CYL)	(□○○)	(□○○)	○	○	○	○	______
OIL TEMP OUT OF FRAME	(□○○)	(□○○)	○	○	○	○	______
HIGH GAS DISCH. TEMP. EACH CYLINDER	(□○○)	(□○○)	○	○	○	○	______
HIGH JACKET WATER TEMP., EA. CYL.	(□○○)	(□○○)	○	○	○	○	______
LOW SUCTION PRESS., FIRST STG INLET	(□○○)	(□○○)	○	○	○	○	______
HI DISCH. PRESSURE ○ FINAL ○ EA STG	(□○○)	(□○○)	○	○	○	○	______
HI CYL. GAS Δ P, EACH STAGE	(□○○)	(□○○)	○	○	○	○	______
HI LIQ. LEV., EA. MOISTURE SEPARATOR	(□○○)	(□○○)	○	○	○	○	______
LOW PURGE GAS PRESS, DISTANCE PIECE(S)	(□○○)	(□○○)	○	○	○	○	______
HI X-HD PIN TEMP	(□○○)	(□○○)	○	○	○	○	______
PRESS PKG CASE (PISTON ROD TEMP)	(□○○)	(□○○)	○	○	○	○	______
______	(□○○)	(□○○)	○	○	○	○	______
			TOTAL NUMBER OF ANNUNCIATION POINTS				______

SWITCH CONTACT OPERATION NOTE: EACH SWITCH SHALL BE MINIMUM SPDT ARRANGEMENT

ALARM CONTACTS SHALL: ○ OPEN (DE-ENERGIZED) TO SOUND ALARM & BE ENERGIZED WHEN COMPRESSOR IS IN OPERATION
○ CLOSE (ENERGIZE) TO SOUND ALARM & BE DE-ENERGIZED WHEN COMPRESSOR IS IN OPERATION

SHUTDOWN CONTACTS SHALL: ○ OPEN (DE-ENERGIZED) TO SHUTDOWN & BE ENERGIZED WHEN COMPRESSOR IS IN OPERATION
○ CLOSE (ENERGIZE) TO SHUTDOWN & BE DE-ENERGIZED WHEN COMPRESSOR IS IN OPERATION

REF: 3.6.5.1 FOR MINIMUM RECOMMENDED PROTECTION REQUIREMENTS

RECIPROCATING COMPRESSOR DATA SHEET—CUSTOMARY UNITS

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☐ INSTRUMENTATION (CONT'D)

○ MISCELLANEOUS INSTRUMENTATION ○ INTERCOOLER(S) ○ AFTERCLR ○ OIL CLR ○ H_2O CLR

SIGHT FLOW IND. (COOLING H_2O ONLY)	(☐○○) FOR	○ CYL JACKET WATER ○ ROD PRESS. PACKING CASES
PNEUMATIC PRESSURE TRANSMITTERS	(☐○○) FOR:	______
PRESSURE TRANSMITTERS (ELEC. OUTP.)	(☐○○) FOR:	______
PNEUMATIC LEVEL TRANSMITTERS	(☐○○)	______
ALARM HORN & ACKN'LMT TEST BUTTON	(☐○○)	______
CONDUIT & WIRING W/JUNCT. BOXES (CONSOLES)	(☐○○)	______
TEST VALVES	(☐○○) FOR:	______
DRAIN VALVES	(☐○○) FOR:	______
GAUGE GLASS(ES)	(☐○○) FOR:	______
TACHOMETER	(☐○○)	______ SPEED RANGE ______ TO ______ RPM
CRANKSHAFT KEY PHASER AND TRANSDUCER	(☐○○) FOR:	______
______	(☐○○)	______
______	(☐○○)	______

○ SEPARATE LUBE OIL CONSOLE INSTRUMENTATION: PURCH. TO LIST REQ'MTS IN ADDITION TO ANY ABOVE REQ'MTS

______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______

○ SEPARATE COOLING WATER CONSOLE INSTRUMENT: PURCH. TO LIST REQ'MTS IN ADDITION TO ANY ABOVE REQ'MTS

______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______
______	(☐○○)	______

☐ RELIEF VALVES

LOCATION	BY	MANUFACTURER	TYPE	◇ SIZE	◇ SETTING
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______
______	(☐○○)	______	______	______	______

NOTES: SEE MOTOR DATA SHEET FOR ADDITIONAL MOTOR INSTRUMENTATION REQUIREMENTS
FOR TURBINE DRIVERS USE APPLICABLE API DATA SHEETS
FOR GEAR REDUCERS USE APPLICABLE API DATA SHEETS
ELECTRICAL & INSTRUMENTATION CONNECTIONS SHALL BE MADE DIRECTLY BY THE PURCHASER TO INDIVIDUAL INSTRUMENTS ON THE COMPRESSOR

ADDITIONAL INSTRUMENTATION REMARKS/SPECIAL REQUIREMENTS:

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RECIPROCATING COMPRESSOR DATA SHEET—SI UNITS

JOB NO. ______ ITEM NO. ______
PURCH. ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT

FOR/USER ______ SITE/LOCATION ______ SERVICE ______ NO. REQ'D. ______

NOTE: ○ INDICATES INFO. TO BE COMPLETED BY PURCH. □ BY MANUFACTURER WITH PROPOSAL ◇ BY MANUFACTURER AFTER ORDER ⊡ BY MANUFACTURER OR PURCHASER AS APPLICABLE

COMPR. MFGR. ______ TYPE MODEL NO(S) ______ SERIAL NO(S) ______

COMPR. THROWS: TOTAL NO. ______ NO. WITH CYLS. ______ NOMINAL FRAME RATING ______ BkW @ RATED RPM OF ______

□ MAX/MIN ALLOWABLE SPEED ______ / ______ RPM

DRIVER MFGR. ______ DRIVER NAMEPLATE kW/OPERATING RPM ______ / ______

DRIVE SYSTEM: ○ DIRECT COUPLED ○ GEARED & COUPLED ○ V-BELT

TYPE OF DRIVER: ○ IND. MOTOR ○ SYN. MOTOR ○ STEAM TURBINE ○ GAS TURBINE ○ ENGINE ○ OTHER ______

NO NEGATIVE TOLERANCE APPLIES: ○ YES - PURCHASER TO FILL IN "REQUIRED CAPACITY" LINES. CYLINDERS: ○ LUBE

(NNT) ○ NO - PURCHASER TO FILL IN "MFGR.'S RATED CAP." LINES ○ NON-LUBE

○ MAX ACCEPTABLE AVG PISTON SPEED ______ m/s

OPERATING CONDITIONS (EACH MACHINE)

○ SERVICE OR ITEM NO.						
○ STAGE						
○ NORM . OR ALT. CONDITION						
○ CERTIFIED PT. (√) CHECK ONE						
○ MOLECULAR WEIGHT						
○ Cp/Cv (K) @65 °C OR ______ °C						

INLET CONDITIONS AT INLET TO: ○ PULSE DEVICES ○ COMPRESSOR CYLINDER FLANGES

NOTE: ○ SIDE STREAM TO ______ STAGE(S), THESE INLET PRESSURES ARE FIXED

○ PRESSURE (k-Pa-abs) (BAR) @ PUL. SUPP. INLET						
⊡ PRESSURE (k-Pa-abs) (BAR) @ CYL. FLANGE						
○ TEMPERATURE (°C)						
○ REF: SIDE STREAM TEMPS (°C)						
□ COMPRESSIBILITY (Z_s)						

INTERSTAGE: INTERSTAGE Δ P INCLUDES: ○ PULSE DEVICES ○ PIPING ○ COOLERS ○ SEPARATORS ○ OTHER ______

⊡ Δ P BETWEEN STAGES, %/(kPa)(BAR)	/	/	/	/	/

DISCHARGE CONDITIONS: AT OUTLET FROM: ○ PULSE DEVICE ○ COMP CYL FLANGES ○ OTHER ______

⊡ PRESSURE (k-Pa-abs) (BAR) @ CYL. FLANGE						
○ PRESSURE (k-Pa-abs) (BAR) @ PUL. SUPP OUTLET						
□ TEMPERATURE, ADIABATIC, °C						
□ TEMPERATURE, PREDICTED, °C						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG})						

***REQUIRED CAPACITY,** RATED FOR PROCESS, AT INLET TO COMPRESSOR, NO NEGATIVE TOLERANCE (-0%)

○ kg/h CAPACITY SPECIFIED IS ○ WET ○ DRY						
○ m_n^3/h (760mm HG & O°C)						

MGFR.'S RATED CAPACITY (AT INLET TO COMPRESSOR) & kW @ CERTIFIED TOLERANCE OF ±3% FOR CAP. & ±3% FOR kW

⊡ kg/h CAPACITY SPECIFIED IS ○ WET ○ DRY						
⊡ INLET m³/h						
⊡ m_n^3/h (760mm HG & O°C)						
□ kW/STAGE						
□ TOTAL BkW @ COMPRESSOR SHAFT						
□ TOTAL kW INCLUDING V-BELT & GEAR LOSSES						

*CAPACITY FOR NNT

MANUFACTURER'S = REQUIRED ÷ 0.97

∴ REQUIRED = MANUFACTURER'S X 0.97

REMARKS/SPECIAL REQUIREMENTS ______

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BY ______________

GAS ANALYSIS AT OPERATING CONDITIONS MOLE % (BY VOLUME) ONLY								REMARKS
O SERVICE/ITEM NO.								
O STAGE								
O NORMAL OR ALT								
		MW						
AIR		28.966						
OXYGEN	O_2	32.000						
NITROGEN	N_2	28.016						
WATER VAPOR	H_2O	18.016						
CARBON MONOXIDE	CO	28.010						
CARBON DIOXIDE	CO_2	44.010						
HYDRO. SULFIDE	H_2S	34.076						
HYDROGEN	H_2	2.016						
METHANE	CH_4	16.042						
ETHYLENE	C_2H_4	28.052						
ETHANE	C_2H_6	30.068						
PROPYLENE	C_3H_6	42.078						
PROPANE	C_3H_8	44.094						
I-BUTANE	C_4H_{10}	58.120						
n-BUTANE	C_4H_{10}	58.120						
I-PENTANE	C_5H_{12}	72.146						
n-PENTANE	C_5H_{12}	72.146						
HEXANE PLUS								
AMMONIA	NH_3	17.031						
HYDRO. CHLORIDE	HCl	36.461						
CHLORINE	Cl	70.914						
CHLORIDES - TRACES								
☐ CALCULATED MOL WT.								
☐ Cp/Cv (K) @ 65° OR ______ °C								

NOTE: IF WATER VAPOR AND/OR CHLORIDES ARE PRESENT, EVEN IN MINUTE TRACES, IN THE GAS BEING COMPRESSED, IT MUST BE INCLUDED ABOVE.

APPLICABLE SPECIFICATIONS

O API-618-RECIPROCATING COMPRESSORS FOR PETROLEUM, CHEMICAL AND GAS INDUSTRY SERVICES

NACE MR-0175 (2.14.1.10)

O ______________
O ______________
O ______________
O ______________
O ______________
O ______________
O ______________
O ______________
O ______________

SITE/LOCATION CONDITIONS

ELEVATION ______ m BAROMETER ______ BAR (kPa abs) AMBIENT TEMPS: MAX ______ °C MIN ______ °C

O MIN DESIGN METAL TEMP ______ °C (2.14.8.1) RELATIVE HUMIDITY: MAX: ______ % MIN ______ %

COMPRESSOR LOCATION O INDOOR O HEATED O UNHEATED O AT GRADE LEVEL O ELEVATED: ______ m

O OUTDOOR O NO ROOF O UNDER ROOF O PARTIAL SIDES O PLATFORM O ON-SHORE

O OFF-SHORE O WEATHER PROTECTION REQ. O TROPICALIZATION REQ.

O WINTERIZATION REQUIRED

UNUSUAL CONDITIONS: O CORROSIVES O DUST O FUMES O OTHER ______________

____

ELECTRICAL CLASSIFICATIONS

	HAZARDOUS	NON-HAZARDOUS
MAIN UNIT	O ZONE ______ GAS GROUP ______ TEMP. CLASS ______	O
LO CONSOLE	O ZONE ______ GAS GROUP ______ TEMP. CLASS ______	O
CW CONSOLE	O ZONE ______ GAS GROUP ______ TEMP. CLASS ______	O

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PART LOAD OPERATING CONDITIONS

CAPACITY CONTROL BY: O MFG'S CAP. CONTROL O PURCHASERS BY-PASS O BOTH O OTHER ____________

FOR: O PART LOAD COND. O START-UP ONLY BOTH O

WITH: O AUTO LOADING DELAY INTERLOCK (3.6.2.2) O AUTO IMMEDIATE UNLOADING

USING: O FIXED VOLUME POCK O SUCTION VALVE UNLOADERS: O FINGER O PLUG OTHER ________

ACTION : O DIRECT (AIR-TO-UNLOAD) O REVERSE (AIR-TO-LOAD/FAIL SAFE)

NUMBER OF STEPS: O ONE O THREE O FIVE O OTHER ________

O RAIN COVER REQUIRED OVER UNLOADERS

ALL UNLOADING STEPS BASIS MANUFACTURERS CAPACITY SHOWN ON PAGE 1.

INLET AND DISCHARGE PRESSURE ARE O AT CYLINDER FLANGES O PULSATION SUPPRESSOR FLANGES

O SERVICE OR ITEM NO.						
☐ STAGE						
☐ NORM. OR ALT. CONDITION						
O PERCENT CAPACITY						
O WEIGHT FLOW, kg/h						
☐ m³/h (760mm Hg & 0°C)						
☐ POCKETS/VALVES OPERATION*						
☐ POCKET CLEARANCE ADDED %						
☐ TYPE UNLOADERS, PLUG/FINGER						
☐ INLET TEMPERATURE. °C						
☐ INLET PRESSURE, (kPa-abs)(BAR)						
☐ DISCHARGE PRESSURE, (kPa-abs)(BAR)						
☐ DISCHARGE TEMP., ADIABATIC °C						
☐ DISCHARGE TEMP., PREDICTED, °C						
☐ VOLUMETRIC EFF., %HE/%CE	/	/	/	/	/	/
☐ CALC. GAS ROD LOAD, kN, C**						
☐ CALC. GAS ROD LOAD, kN, T**						
◇ COMB. ROD LOAD, kN C (GAS & INERTIA)						
◇ COMB. ROD LOAD, kN T (GAS & INERTIA)						
◇ ROD REV., DEGREES MIN @ X-HD PIN ***						
☐ BkW/STAGE						
☐ TOTAL kW @ COMPRESSOR SHAFT						
☐ TOTAL kW INCL. V-BELT & GEAR LOSSES						

* SHOW OPERATION WITH THE FOLLOWING SYMBOLS:

HEAD END = HE
OR
CRANK END = CE

PLUS

SUCTION VALVE(S) UNLOADED = S
OR
FIXED POCKET OPEN = F
OR
VARIABLE POCKET OPEN = V

EXAMPLE: HE-F/CE-S = HEAD END FIXED POCKET OPEN/CRANK END SUCTION VALVE(S) UNLOADED

C = COMPRESSION T = TENSION * X - HD = CROSSHEAD

☐ MINIMUM PRESSURE REQUIRED TO OPERATE CYLINDER UNLOADING DEVICES, ________ (BARG)(kPa)

CYLINDER UNLOADING MEDIUM: O AIR O NITROGEN O OTHER ____________

O PRESSURE AVAILABLE FOR CYLINDER UNLOADING DEVICES, MAX/MIN _____/_____ (BARG)(kPa)

REMARKS, SPECIAL REQUIREMENTS, AND/OR SKETCH

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○ **SCOPE OF BASIC SUPPLY**

PURCHASER TO FILL IN (□○○) AFTER COMMODITY TO INDICATE: □ BY COMPR. MFR. ○ BY PURCH. ○ BY OTHERS

○ DRIVER (□○○) ○ VARIABLE SPEED SPEED RANGE ______ RPM TO ______ RPM
○ INDUCTION MOTOR ○ SYNCHRONOUS MOTOR ○ STEAM TURBINE ○ ENGINE ○ OTHER __________
○ API-541 ○ API-546 ○ API-611 ○ API-612
○ OUTBOARD BEARING ○ PROVISION FOR DRY AIR PURGE FOR OUTBOARD BEARING
○ SLIDE BASE FOR DRIVER (□○○) SOLE PLATE FOR DRIVER (□○○)
○ MOTOR STARTING EQUIPMENT (□○○) / DEFINE ______________________________]
○ GEAR (□○○): ○ BASEPLATE FOR GEAR ○ API-613 ○ API-677
○ COUPLING(S) (□○○): ○ LOW SPD. ○ HI-SPD. ○ QUILL SHAFT ○ KEYLESS DRIVE ○ KEYED DRIVE ○ OTHER __________
○ API-671
○ V-BELT DRIVE (□○○): ○ SHEAVES & V-BELTS (□○○): ○ STATIC CONDUCTION V-BELTS ○ BANDED V-BELTS
○ DRIVE GUARD(S) (□○○): ○ MANUFACTURER'S STD. ○ NON-SPARKING ○ CALIF CODE ○ API-671 APPENDIX C
○ OTHER ______________________________

○ PULSATION SUPPRESSORS WITH INTERNALS (□○○): ○ INITIAL INLET & FINAL DISCHARGE ○ SUPPORTS (□○○)
○ INTERSTAGE ○ SUPPORTS (□○○)
○ PULSATION SUPPRESSORS WITHOUT INTRNL (□○○): ○ INITIAL INLET & FINAL DISCHARGE ○ SUPPORTS (□○○)
○ INTERSTAGE ○ SUPPORTS (□○○)
○ SUPPRESSOR(S) TO HAVE MOISTURE REMOVAL SECTION: ○ INITIAL INLET ONLY ○ ALL INLET SUPPRESSORS
○ ACOUSTICAL SIMUL. STUDY (□○○ DESIGN APPROACH (Check Only One) ○ 1 ○ 1, W/SIMPLIFIED ANALYSIS OF PIPING SYSTEM
□ DIGITAL □ ANALOG ○ 2, SEE 3.9.2.1 AND APPENDIX M
○ 3, SEE 3.9.2.1 AND APPENDIX M
NOTE: SEE APPENDIX N FOR INFORMATION REQUIRED FOR STUDY
STUDY TO CONSIDER: ALL SPECIFIED LOAD COND., INCL ○ SINGLE ACT., PLUS
○ COMP. OPER. IN PARALLEL ○ ALTERNATE GASES
○ WITH EXISTING COMPRESSORS AND PIPING SYSTEMS
○ STUDY TO BE WITNESSED ○ COMPRESSOR VALVE DYNAMIC RESPONSE
○ VENDOR REVIEW OF PURCHASERS PIPING ARRANGEMENT ○ PULSATION SUPPRESSION DEVICE LOW CYCLE FATIGUE ANALYSIS
○ PIPING SYSTEM FLEXIBILITY

PACKAGED: ○ NO ○ YES (□○○) DEFINE BASIC SCOPE OF PACKAGING IN REMARKS SECTION, PAGE 5
○ SKID ○ SOLEPLATE ○ BASEPLATE ○ BOLTS OR STUDS FOR SOLEPLATE TO FRAME ○ RAILS ○ CHOCK BLOCKS ○ SHIMS
○ SUITABLE FOR COLUMN MOUNTING (UNDER SKID AND/OR BASEPLATE)
○ LEVELING SCREWS ○ NON-SKID DECKING ○ SUB SOLEPLATES
○ DIRECTED GROUTED ○ CEMENTED/MORTAR GROUT ○ EPOXY GROUT; MFG/TYPE __________ / __________
○ INTERCOOLER(S) (□○○) ○ SEPARATOR(S) (□○○) ○ AFTERCOOLER(S) (□○○) **INTERCOOLERS:**
○ INTERSTAGE PIP. (□○○): ○ PIPING MATCHMARKED ○ SHOP FITTED ○ MACHINE MOUNTED
○ CONDENSATE SEPARATION & COLLECTION FACILITY SYSTEM PER 3.8.12 ○ OFF MOUNTED
○ INLET STRAINER(S) (□○○): ○ INITIAL INLET ○ SIDESTREAM INLET ○ SPOOL PIECE FOR INLET STRAINERS
○ MANIFOLD PIPING: ○ DRAINS ○ VENTS ○ RELIEF VALVES ○ AIR/GAS SUPPLY **FLANGE FINISH**
○ RELIEF VALVE(S) (□○○): ○ INITIAL INLET ○ INTERSTAGE ○ FINAL DISCHARGE ○ API-618 FLANGE FINISH REF. 3.9.3.15 > 125< 250
○ RUPTURE DISC(S) (□○○): ○ THRU STUDS IN PIPING FLANGES ○ FLANGE FINISH PER ANSI 16.5
○ CRANKCASE RAPID PRESSURE RELIEF DEVICE(S) (□○○): ○ SPECIAL FINISH __________
○ SPECIAL PIPING REQUIREMENTS PER 3.7.1.12.24. (DEFINE IN REMARKS SECTION NEXT PAGE)

○ INITIAL INLET, ○ INTERSTAGE SUCTION PIPING ARR'D FOR: ○ INSULATION (□○○) ○ HEAT TRACING (□○○)
○ FOR ATMOSPHERIC INLET AIR COMPR. ONLY: ○ INLET AIR FILTER (□○○) ○ INLET FILTER-SILENCER (□○○)
○ PREFERRED TYPE OF CYLINDER COOLING (□○○) ○ FORCED ○ THERMOSYPHON __________ STAGE CYL'(S)
○ STATIC (STAND-PIPE) __________ STAGE CYL'(S)
NOTE: MANUFACTURER SHALL RECOMMEND BEST TYPE OF COOLING AFTER FINAL ENGINEERING REVIEW OF ALL OPERATING CONDITIONS
○ CYL. COOLING WATER PIPING (□○○) ○ MATCHMARKED
○ SINGLE INLET/OUTLET MANIFOLD & VALVES ○ SIGHT GLASS(ES)
○ INDIVIDUAL INLET/OUTLET PER CYL. ○ VALVE(S)
○ CLOSED SYS. WITH WATER PUMP, COOLER, SURGE TANK, & PIPING
○ SHOP RUN ○ ARRANGED FOR HEATING JACKET AS WELL AS COOLING

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SCOPE OF BASIC SUPPLY (Cont)

○ SEPARATE COOLING CONSOLE (□○○): ○ ONE FOR EA. UNIT ○ ONE COMMON TO ALL UNITS ○ DUAL PUMPS (AUX. & MAIN)
○ ARRANGED FOR HEATING JACKET WATER AS WELL AS COOLING
FRAME LUBE OIL SYSTEM (□○○): ○ AUX PUMP ○ DUAL FILTERS WITH TRANSFER VALVE ○ SHOP RUN
○ CONTINUOUS FLOW IN SENSING LINE TO PRESSURE SWITCHES
○ SEPARATE LUBE OIL CONSOLE (□○○): ○ EXTENDED TO MOTOR OUTBOARD BEARING ○ SHOP RUN
API-614 APPLIES (REFER TO NOTE OF 2.12.2) ○ NO ○ YES
NOTE: PIPING BETWEEN ALL CONSOLES AND COMPRESSOR UNIT BY PURCHASER

○ CAPACITY CONTROL (□○○) ○ SEE DATA SHEET PAGE 3 FOR DETAILS ○ IN INSTRUMENT & CONTROL PANEL
○ SEPARATE MACHINE MOUNTED PANEL ○ SEPARATE FREE STANDING PANEL
○ PNEUMATIC ○ ELECTRIC ○ ELECTRONIC ○ HYDRAULIC
○ PROGRAMMABLE CONTROLLER
○ INSTRUMENT & CONTROL PANEL (□○○): ○ ONE FOR EACH UNIT ○ ONE COMMON TO ALL UNITS
○ MACHINE MOUNTED ○ FREE STANDING (OFF UNIT)
SEE INSTRUMENTATION DATA SHEETS FOR DETAILS OF PANEL, ADDITIONAL REMARKS, AND INSTRUMENTATION
NOTE: ALL TUBING, WIRING, & CONNECTIONS BETWEEN OFF-UNIT FREE STANDING PANELS AND COMPRESSOR UNIT BY PURCHASER

○ HEATERS (□○○): ○ FRAME LUBE OIL ○ CYL. LUBRICATORS ○ COOLING WATER ○ DRIVER(S) ○ GEAR OIL
○ ELECTRIC ○ STEAM

○ BARRING DEVICE (□○○): ○ MANUAL ○ PNEUMATIC ○ ELECTRIC ○ FLYWHEEL LOCKING DEVICE (□○○)
○ ROD PRESSURE PACKING COOLING SYSTEM (□○○): ○ SEPARATE CONSOLE ○ FILTERS
○ SPECIAL CORROSION PROTECTION: ○ NO ○ YES ○ MFR'S STANDARD ○ OTHER ____________
○ HYDRAULIC TENSIONING TOOLS ○ NO ○ YES
○ MECHANICAL RUN TEST: ○ NO ○ YES ○ MFG'S STANDARD ○ OTHER ____________
○ COMPLETE SHOP RUN TEST OF ALL MACHINE MOUNTED EQUIPMENT, PIPING, & APPURTENANCES

PAINTING: ○ MANUFACTURER'S STANDARD ○ SPECIAL ____________
NAMEPLATES: ○ U.S. CUSTOMARY UNITS ○ SI UNITS
SHIPMENT: ○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED (□○○)
○ STANDARD 6 MONTH STORAGE PREPARATION (□○○), PER SPEC ____________
○ OUTDOOR STORAGE FOR OVER 6 MONTHS (□○○), PER SPEC ____________
○ INITIAL INSTALLATION AND OPERATING TEMP ALIGNMENT CHECK AT JOBSITE BY VENDOR REPRESENTATIVE

○ COMPRESSOR MANUFACTURER'S USER'S LIST FOR SIMILAR SERVICE
○ PERFORMANCE DATA REQUIRED PER 5.3.3: ○ BkW VS. SUCTION PRESSURE CURVES
○ ROD LOAD/GAS LOAD CHARTS
○ VALVE FAILURE DATA CHARTED
○ SPEED/TORQUE CURVE DATA
○ BkW VS CAPACITY PERFORMANCE CURVES OR TABLES REQUIRED FOR UNLOADING STEPS AND/OR VARIABLE SUCTION/DISCHARGE PRESSURES

REMARKS/SPECIAL REQUIREMENTS: ____________

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UTILITY CONDITIONS

ELECTRICAL POWER: AC VOLTS / PHASE / HERTZ DC VOLTS | AC VOLTS / PHASE / HERTZ DC VOLTS

○ MAIN DRIVER ____ / ____ / ____ / ____ INSTRUMENT ____ / ____ / ____ / ____
○ AUXILIARY MOTORS ____ / ____ / ____ / ____ ALARM & SHUTDOWN ____ / ____ / ____ / ____
○ HEATERS ____ / ____ / ____ / ____ ____ ____ / ____ / ____ / ____

INSTRUMENT AIR: NORMAL PRESSURE ____ PSIG MAX/MIN ____ / ____ PSIG

STEAM FOR:

DRIVERS			HEATERS		
INLET: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)	INLET: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)
(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C	(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C
EXHAUST: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)	EXHAUST: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)
(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C	(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C

COOLING WATER FOR:

COMPRESSOR CYLINDERS			COOLERS		
TYPE WATER	____		TYPE WATER	____	
SUPPLY: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)	SUPPLY: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)
(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C	(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C
RETURN: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)	RETURN: PRESS	____ (BARG) (kPa)	MAX/MIN ____ / ____ (BARG) (kPa)
(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C	(NORMAL) TEMP	____ °C	MAX/MIN ____ / ____ °C

COOLING FOR ROD PACKING:
TYPE FLUID ____ SUPPLY PRESS ____ (BARG) (kPa) @ ____ °C RETURN ____ @ ____ °C

FUEL GAS: NORMAL PRESSURE ____ (BARG) (kPa) MAX/MIN ____ / ____ (BARG) (kPa) LHV ____ MJ/m³
COMPOSITION ____

REMARKS/SPECIAL REQUIREMENTS:

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☐ CYLINDER DATA AT FULL LOAD CONDITION						
SERVICE ITEM NO.						
STAGE						
INLET PRESSURE, (BARG) (kPa) } @ CYLINDER FLANGES						
DISCHARGE PRESSURE, (BARG) (kPa) } @ CYLINDER FLANGES						
CYLINDERS PER STAGE						
SINGLE OR DOUBLE ACTING (SA OR DA)						
BORE, mm						
STROKE, mm						
RPM: RATED/MAX ALLOW	/					
PISTON SPEED, m/s: RATED/MAX ALLOW	/					
CYLINDER LINER, YES/NO						
LINER NOMINAL THICKNESS, mm						
PISTON DISPLACEMENT, m^3/h						
CYLINDER DESIGN CLEARANCE, % AVERAGE						
VOLUMETRIC EFFICIENCY, % AVERAGE						
VALVES, INLET/DISCHARGE, QTY PER CYL.	/	/	/	/	/	/
TYPE OF VALVES						
VALVE LIFT, INLET/DISCHARGE, mm	/	/	/	/	/	/
VALVE VELOCITY, API 4TH EDITION, m/s						
SUCTION VALVE(S)						
DISCHARGE VALVE(S)						
ROD DIAMETER, mm						
MAX ALLOW. COMBINED ROD LOADING, kN, C *						
MAX ALLOW. COMBINED ROD LOADING, kN, T *						
CALCULATED GAS ROD LOAD, kN, C *						
CALCULATED GAS ROD LOAD, kN, T *						
COMBINED ROD LOAD (GAS+INERTIA), kN, C *						
COMBINED ROD LOAD (GAS+INERTIA), kN, T *						
ROD REV., DEGREES MIN @ X-HD PIN **						
RECIP WT. (PISTON, ROD, X-HD & NUTS), kg **						
MAX ALLOW, WORKING PRESSURE, (BARG) (kPa)						
MAX ALLOW, WORKING TEMPERATURE, °C						
HYDROSATIC TEST PRESSURE, (BARG) (kPa)						
HELIUM TEST PRESSURE, (BARG) (kPa)						
INLET FLANGE SIZE/RATING	/	/	/	/	/	/
FACING						
DISCHARGE FLANGE SIZE/RATING	/	/	/	/	/	/
FACING						
DISCHARGE RELIEF VALVE SETTING BASED ON DATA FOR INLET PRESSURES GIVEN ABOVE:						
RECOMMENDED SETTING, (BARG) (kPa)						
GAS ROD LOAD, kN, C *						
GAS ROD LOAD, kN, T *						
COMBINED ROD LOAD, kN, C *						
COMBINED ROD LOAD, kN, T *						
ROD REVERSAL, DEGREE MIN. @ X-HD PIN ** NOTE: CALCULATED AT INLET PRESSURES GIVEN ABOVE & RECOMMENDED PSV SETTING						
○ SETTLE-OUT GAS PRESSURE (DATA REQUIRED FOR STARTING)						

*C = COMPRESSION *T = TENSION

** X-HD = CROSSHEAD

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1	☐ **CONSTRUCTION FEATURES**						
2	SERVICE ITEM NO.						
3	STAGE						
4	CYLINDER SIZE (BORE DIA), mm						
5	ROD RUN-OUT: NORMAL COLD VERTICAL (per appendix C)						
6	**MATERIALS OF CONSTRUCTION**						
7	CYLINDER(S)						
8	CYLINDER LINER(S)						
9	PISTON(S)						
10	PISTON RINGS						
11	WEAR BANDS ○ REQUIRED	/	/	/	/	/	/
12	PISTON ROD(S): MATERIAL/YIELD, N/mm²						
13	THREAD ROOT STRESS @ MACRL * @X-HD END						
14	PISTON ROD HARDNESS, BASE MATERIAL, Rc						
15	PISTON ROD COATING ⊗ REQUIRED						
16	COATING HARDNESS, Rc	/	/	/	/	/	/
17	VALVE SEATS/SEAT PLATE						
18	VALVE SEAT MIN HARDNESS, Rc						
19	VALVE GUARDS (STOPS)						
20	VALVE DISCS						
21	VALVE SPRINGS						
22	ROD PRESSURE PACKING RINGS						
23	ROD PRESSURE PACKING CASE						
24	ROD PRESSURE PACKING SPRINGS						
25	SEAL/BUFFER PACKING, DISTANCE PIECE						
26	SEAL/BUFFER PACKING, INTERMEDIATE						
27	WIPER PACKING RINGS						
28	MAIN JOURNAL BEARINGS, CRANKSHAFT						
29	CONNECTING ROD BEARING, CRANKPIN						
30	CONNECTING ROD BUSHING, X-HD END						
31	CROSSHEAD (X-HD) PIN BUSHING						
32	CROSSHEAD PIN						
33	CROSSHEAD						
34	CROSSHEAD SHOES						
35	CYLINDER INDICATOR VALVES (✓)						
36	INDICATOR CONNECTIONS ABOVE 345 BAR						
37	FLUOROCARBON SPRAYED CYLINDER (✓)						
38	INSTRUMENTATION IN (✓) COLD SIDE						
39	CONTACT W/PROCESS GAS (✓) HOT SIDE						
40	*MAXIMUM ALLOWABLE COMBINED ROD LOAD	USE (✓) IN APPROPRIATE COLUMN WHERE APPLICABLE					

41 ☐ COMPRESSOR CYLINDER ROD PACKING

42 ○ FULL FLOATING PACKING

43 ○ VENTED TO: ○ FLARE @ _____ (BARG) (kPa) ○ ATMOSPHERE

44 ○ SUCTION PRESSURE @ _______ (BARG) (kPa)

45 ○ FORCED LUBRICATED ○ NON-LUBE ○ TFE

46 ☐ WATER COOLED, ________ STAGE(S), ______ m³/h REQ'D

47 ☐ OIL COOLED, ___________ STAGE(S), ______ m³/h REQ'D

48 ○ WATER FILTER PROV. FUTURE WATER/OIL COOLING

49 ○ VENT/BUFFER GAS SEAL PACKING ARR. (REF. APPENDIX I FIG I-1)

50 ○ CONSTANT OR ○ VARIABLE DISPOSAL SYSTEM

51 ○ BUFFER GAS PRESSURE, ____________ (BARG) (kPa)

52 ○ SPLASH GUARDS FOR WIPER PACKING

DISTANCE PIECES: ○ TYPE A ○ TYPE B ○ TYPE C ○ TYPE D

Ref: Appendix G, Fig. G-3

COVERS: ○ SOLID METAL ○ SCREEN ○ LOUVERED

CYLINDER COMPARTMENT: (Outboard Distance Piece)
- ○ VENTED TO __________ (BARG)(kPa)
- ○ PURGED AT __________ (BARG)(kPa)
- ○ PRESSURIZED TO _______ (BARG)(kPa)
- ○ WITH RELIEF VALVE

FRAME COMPARTMENT: (Inboard Distance Piece)
- ○ VENTED TO __________ (BARG)(kPa)
- ○ PURGED AT __________ (BARG)(kPa)
- ○ PRESSURIZED TO _______ (BARG)(kPa)
- ○ WITH RELIEF VALVE

☐ DISTANCE PIECE MAWP _______ (BARG)(kPa)

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CONSTRUCTION FEATURES (CONTINUED)

○ FABRICATED CYLINDER, HEADS, & CONNECTION SKETCHES FOR DESIGN REVIEW BY PURCHASER. (2.14.5.2.8)

COUPLING(S)

	○ LOW SPEED Between Compressor & Driver or Gear	○ HIGH-SPEED Between Driver & Gear
◇ BY MANUFACTURER		
◇ MODEL		
◇ TYPE		

API-671 APPLIES ○ YES ○ NO

○ INSPECTION AND SHOP TESTS (REF. 4.1.3)

	REQ'D	WITN.	OBSER.
* SHOP INSPECTION	○	○	○
ACTUAL RUNNING CLEARANCES AND RECORDS	○	○	○
MFG STANDARD SHOP TESTS	⊗	○	○
CYLINDER HYDROSTATIC TEST	⊗	○	○
CYLINDER PNEUMATIC TEST	⊗	○	○
CYLINDER HELIUM LEAK TEST	○	○	○
CYL JACKET WATER HYDRO TEST	⊗	○	○
*MECHANICAL RUN TEST (4 HR)	○	○	○
BAR-OVER TO CHECK ROD RUNOUT	⊗	○	○
*LUBE OIL CONSOLE RUN/TEST (4 HR)	○	○	○
*COOLING H_2O CONSOLE RUN/TEST	○	○	○
RADIOGRAPHY BUTT WELDS ○ GAS ○ OIL ○ FAB CYLS	○	○	○
MAG PARTICLE/LIQUID PENETRANT OF WELDS SPECIFY ADDITIONAL REQUIREMENTS (4.2.1.3)	○	○	○
____	○	○	○
QC OF INACCESSIBLE WELDS (2.14.5.2.4)	○		
SHOP FIT-UP OF PULSATION SUPPL DEVICES & ALL ASSOCIATED GAS PIPING	○	○	○
*CLEANLINESS OF EQUIP., PIPING, & APPURTENANCES	○	○	○
*HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES	○	○	○
*NOTIFICATION TO PURCHASER OF ANY REPAIRS TO MAJOR COMPONENTS	○		
____	○	○	○
____	○	○	○

*SPECIFIC REQUIREMENTS TO BE DEFINED, FOR EXAMPLE, DISMANTLING, AUX EQUIPMENT OPERATIONAL & RUN TESTS.

APPENDIX K COMPLIANCE: ○ VENDOR ○ PURCHASER

○ BUFFER GAS PACKING ARR. Ref: Appendix I Figures I-1, I-2 & I-3
○ OIL WIPER PACKING PURGE
○ INTERMEDIATE PARTITION PURGE
INERT BUFFER/PURGE GAS: ○ N_2 ○ OTHER ____
○ VENT, DRAIN, PURGE PIPING BY MFG'R ○ NO ○ YES

☐ V-BELT DRIVE

	DRIVEN SHEAVE (Compressor Shaft)	DRIVE SHAFT (Driver shaft)
RPM (EXPECTED)		
PITCH DIA. (Inches)		
◇ QTY & GROOVE X-SEC		
POWER TRANSMITTED		Incl. Belt Losses

DRIVER NAMEPLATE kW RATING ____
◇ CENTER DISTANCE (INCHES) ____
◇ QTY, TYPE, X-SEC., & LENGTH BELTS ____
◇ BELT SERVICE FACTOR (RELATIVE TO DRIVER NAMEPLATE HP RATING ____

CYLINDER LUBRICATION

○ NON-LUBE ____ STAGE(S)/SERVICE
○ LUBRICATED ____ STAGE(S)/SERVICE
TYPE OF LUBE OIL ○ SYNTHETIC ____
○ HYDROCARBON ____
LUBRICATOR DRIVE BY: ☐ COMP. CRANKSHAFT, DIRECT
☐ CHAIN, FROM CRANKSHAFT
☐ ELECTRIC MOTOR
☐ OTHER ____
◇ LUBRICATOR MFR ____
◇ MODEL ____
TYPE LUBRICATOR: (2.13) ○ SINGLE PLUNGER PER POINT
○ DIVIDER BLOCKS
◇ COMPARTMENT, TOTAL QTY ____
◇ PLUNGERS (PUMPS), TOTAL QTY ____
◇ SPARE PLUNGERS, QTY ____
◇ SPARE COMPARTMENT W/OUT PLUNGERS ____
○ HEATERS: ○ ELECTRIC W/THERMOSTAT ○ STEAM

☐ ESTIMATED WEIGHTS AND NOMINAL DIMENSIONS

☐ TOTAL COMPR. WT, LESS DRIVER & GEAR ____ kg
◇ WT, OF COMPLETE UNIT, (LESS CONSOLES) ____ kg
◇ MAXIMUM ERECTION WEIGHT ____ kg
◇ MAXIMUM MAINTENANCE WEIGHT ____ kg
◇ DRIVER WEIGHT/GEAR WEIGHT ____ / ____ kg
◇ LUBE OIL/COOLING H_2O CONSOLE ____ / ____ kg
◇ FREE STANDING PANEL ____ kg

SPACE REQUIREMENTS-m:	LENGTH	WIDTH	HEIGHT
◇ COMPLETE UNIT			
◇ LUBE OIL CONSOLE			
◇ COOLING H_2O CONSOLE			
◇ FREE STANDING PANEL			

☐ PISTON ROD REMOVAL DIST. ____

OTHER EQUIPMENT SHIPPED LOOSE (DEFINE)
◇ PULSATION SUPPRESSOR, WEIGHT ____ kg
◇ PIPING ____ kg
◇ INTERSTAGE EQUIPMENT ____ kg

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☐ UTILITY CONSUMPTION

ELECTRIC MOTORS

For Induction Motors See Note of 3.1.2.5 and Motor Data sheet	NAMEPLATE HP	LOCKED ROTOR AMPS	FULL LOAD STEADY STATE AMPS
◇ MAIN DRIVER			
◇ MAIN LUBE OIL PUMP			
◇ AUX LUBE OIL PUMP			
◇ MAIN COOLING WATER PUMP			
◇ AUX COOLING WATER PUMP			
◇ ROD PACKING COOLING PUMP			
◇ CYLINDER LUBRICATOR			

MAIN DRIVER NON-STEADY STATE AMPS AT COMPRESSOR RATED HORSEPOWER (Induction Motors Only)
______ AMPS
@ COMPRESSOR RATED
kW OF ______
@ CURRENT PULSATIONS
OF ______ %

ELECTRIC HEATERS

	WATTS	VOLTS	HERTZ
◇ FRAME OIL HEATER(S)			
◇ COOLING WATER HEATER(S)			
◇ CYL. LUBRICATOR HEATER(S)			

STEAM

	FLOW		PRESSURE		TEMPERATURE	BACK PRESSURE	
◇ MAIN DRIVER	______ kg/h	@	______	(BARG)(kPa)	______ °CTT TO	______	(BARG)(kPa)
◇ FRAME OIL HEATER(S)	______ kg/h	@	______	(BARG)(kPa)	______ °CTT TO	______	(BARG)(kPa)
◇ CYL. LUB. HEATER(S)	______ kg/h	@	______	(BARG)(kPa)	______ °CTT TO	______	(BARG)(kPa)
______	______ kg/h	@	______	(BARG)(kPa)	______ °CTT TO	______	(BARG)(kPa)
______	______ kg/h	@	______	(BARG)(kPa)	______ °CTT TO	______	(BARG)(kPa)

COOLING WATER REQUIREMENTS

	FLOW	INLET TEMP	OUTLET TEMP	INLET PRESS	OUTLET PRESS	MAX PRESS
	m^3/h	°C	°C	(BARG)(kPa)	(BARG)(kPa)	(BARG)(kPa)
☐ CYLINDER JACKETS						
◇ INTERCOOLER(S)						
◇ AFTERCOOLER						
◇ FRAME LUBE OIL COOLER						
◇ ROD PRESSURE PACKING*						
◇ TOTAL QUANTITY, m^3/h						

REMARKS/SPECIAL REQUIREMENTS:

* ROD PACKING COOLANT MAY BE OTHER THAN WATER

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☐ FRAME LUBE OIL SYSTEM

☐ **BASIC LUBE OIL SYSTEM FOR FRAME:** ☐ SPLASH ☐ PRESSURE (FORCED) ○ HEATERS REQUIRED:
REF: TYPE MAIN BEARINGS: ☐ TAPERED ROLLER ☐ PRECISION SLEEVE ○ ELEC. W/ THERMOSTAT(S) ○ STEAM
☐ **PRESSURE SYSTEM:** ○ MAIN OIL PUMP DRIVEN BY: ○ COMP. CRANKSHAFT ○ ELEC. MOTOR ○ OTHER ______
☐ PSV FOR MAIN PUMP EXTERNAL TO CRANKCASE
○ AUX OIL PUMP DRIVEN BY: ○ ELEC. MOTOR ○ OTHER ______
☐ HAND OPERATED PRE-LUBE PUMP FOR STARTING ○ OPERATIONAL TEST & 4 HOUR MECH RUN TEST
○ API-614 LUBE SYSTEM: ○ NO ○ YES (See Note of 2.12.2) ○ CHECK VALVE ON MAIN PUMP (FIG G-5)
○ CONTINUOUS FLOW THROUGH OF OIL (3.7.2.7)
○ **SEP. CONSOLE FOR PRESS. LUBE SYS:** ○ ONE CONSOLE FOR EA. COMP. ○ ONE CONSOLE FOR ______ COMPRESSORS
NOTE: Instrumentation to be listed on Instrumentation Data Sheets ○ CONSOLE TO BE OF DECK PLATE TYPE CONSTRUCTION SUITABLE FOR MULTI-POINT SUPPORT AND GROUTING WITH GROUT & VENT HOLES.
○ ELECTRICAL CLASSIFICATION: CLASS ______, GROUP ______, DIV ______ ○ NON-HAZARDOUS

☐ **BASIC SYS. REQ'MTS (NORM. OIL FLOWS & VOLUMES)**

	FLOW m^3/h	PRESSURE (BARG)(kPa)	VISCOSITY SSU @ 40°C	VISCOSITY SSU @ 100°C	SUMP VOLUME m^3
☐ LUBE OIL					
☐ COMPRESSOR FRAME	______	______	______	______	______
◇ DRIVER	______	______	______	______	______
◇ GEAR	______	______	______	______	______

☐ SYSTEM PRESSURES: ☐ DESIGN ______ (BARG) (kPa) ☐ HYDROTEST ______ (BARG) (kPa)
☐ PRESSURE CONTROL VALVE SETTING ______ (BARG) (kPa) ☐ PUMP RELIEF VALVE(S) SET ______ (BARG) (kPa)

○ **PIPING MATERIALS:**

	CARBON STEEL	STAINLESS STEEL WITH SS FLANGES	STAINLESS STEEL WITH CARBON STEEL FLANGES
○ UPSTREAM OF PUMPS & FILTERS	○	○	○
○ DOWNSTREAM OF FILTERS	○	○	○
○ ______	○	○	○
○ ______	○	○	○

☐ **PUMPS (Gear or Screw Type Only)**	◇ RATED FLOW m^3	◇ PRESSURE (BARG) (kPa)	◇ COLD START REQ'D kW	◇ DRIVER kW	◇ SPEED RPM	COUPLING REQ'D	MECH. SEAL REQ'D
MAIN	______	______	______	______	______	○	○
AUXILIARY	______	______	______	______	______	○	○

☐ PUMP CASING MATERIAL (2.12.3.1): MAIN PUMP ______ AUX PUMP ______
○ GUARD(S) REQ. FOR COUPLING(S): ○ MAIN PUMP ○ AUX PUMP ○ GUARD TYPE OR CODE ______
○ AUXILIARY PUMP CONTROL: ○ MANUAL ○ AUTOMATIC ○ ON-OFF-AUTO SEL. SWITCH: ○ BY PURCH. ○ BY MFR.
○ WIRING TO TERMINAL BOX: ○ BY PURCH ○ BY MFR.
○ SWITCHES ○ RTD'S/THERMOCOUPLES

○ **COOLERS:** ○ SHELL & TUBE ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ MFG'S STD. ○ TEMA C ○ TEMA R (API-660 Data Shts Attached)
○ REMOVABLE BUNDLE ○ WATER COOLED ○ AIR COOLED W/AUTO TEMP CONTROL (API-661 Data Shts Attached)
○ W/BYPASS & TEMP CONTROL VALVE: ○ MANUAL ○ AUTO ○ SEE SEPARATE HEAT EXCHANGER DATA SHEET FOR DETAILS, SPECIFY % GLYCOL ON COOLING WATER SIDE

☐ **FILTER(S)** ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ ASME CODE DESIGN ○ ASME CODE STAMPED
☐ DESIGN PRESSURE, ______ (BAR) (kPa) ☐ Δ P CLEAN, ______ (BAR) (kPa) ☐ Δ P COLLAPSE, ______ (BAR) (kPa)
☐ MICRON RATING, ______ ☐ CARTRIDGE MATERIAL, ______ ◇ CARTRIDGE P/N ______
☐ BONNET MATERIAL, ______ ☐ CASING MATERIAL, ______ ○ FURN. SPARE CARTR., QTY ______

☐ **SYS. COMPONENT SUPP.**	MANUFACTURER	MODEL		MANUFACTURER	MODEL
◇ MAIN PUMP	______	______	◇ OIL COOLER(S)	______	______
◇ AUXILIARY PUMP	______	______	◇ TRANSFER VALVE(S)	______	______
◇ MECHANICAL SEALS	______	______	◇ PUMP COUPLING(S)	______	______
◇ ELECTRIC MOTORS	______	______	◇ SUCTION STRAINER(S)	______	______
◇ STEAM TURBINES	______	______	◇ CHECK VALVE(S)	______	______
◇ OIL FILTER(S)	______	______	◇ ______	______	______

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▣ COOLING WATER SYSTEM

○ **BASIC COOLING SYS. FOR:** ○ COMPRESSOR CYL.(S) ○ INTERCOOLER(S) ○ AFTERCOOLER ○ OIL COOLER(S)
○ HEATERS REQ.'D FOR PRE-HEATING: ○ ELEC. W/THERMOSTAT(S) ○ STEAM

○ **PRESSURE FORCED CIRCULATING SYS:** ○ OPEN, PIPING BY: ○ PURCH ○ MFR. ○ CLOSED, PIPING BY MANUFACTURER
MAIN WATER PUMP DRIVEN BY: ○ ELEC. MOTOR ○ STEAM TURBINE ○ OTHER ________
AUX WATER PUMP DRIVEN BY: ○ ELEC. MOTOR ○ STEAM TURBINE ○ OTHER ________

○ **SEP. CONSOLE FOR COOLING WATER SYS:** ○ ONE CONSOLE FOR EA. COMP. ○ ONE CONSOLE FOR ____ COMPRESSORS
NOTE: Instrumentation to be listed on Instrumentation Data Sheets
○ CONSOLE TO BE OF DECK PLATE TYPE CONSTRUCTION SUITABLE FOR MULTI-POINT SUPPORT AND GROUTING WITH GROUT & VENT HOLES.
○ ELECTRICAL CLASSIFICATION: ZONE ________, GAS GROUP ________, TEMP CLASS ________ ○ NON-HAZARDOUS

▣ **BASIC SYS. REQ'MTS (NORM. COOLING WATER FLOW DATA)** COOLING WATER TO BE ____ % ETHYLENE GLYCOL

	FORCED COOL'G	THERMO SYPHON	STAND PIPE	FLOW m^3/h	PRESSURE (BARG)(kPa)	INLET TEMP °C	OUTLET TEMP °C	SIGHT FLOW INDICATORS
CYLINDER(S), ____ STAGE	○	○	○	____	____	____	____	○
CYLINDER(S), ____ STAGE	○	○	○	____	____	____	____	○
CYLINDER(S), ____ STAGE	○	○	○	____	____	____	____	○
CYLINDER(S), ____ STAGE	○	○	○	____	____	____	____	○
CYLINDER(S), ____ STAGE	○	○	○	____	____	____	____	○
CYLINDER(S), ____ STAGE	○	○	○	____	____	____	____	○
PISTON ROD PACK'G TOTAL	○			____	____	____	____	○
INTERCOOLER(S) TOTAL	○			____	____	____	____	○
AFTERCOLLER	○			____	____	____	____	○
OIL COOLER(S)	○			____	____	____	____	○
________	○			____	____	____	____	○
TOTAL FLOW				____				

□ **SYS. PRESSURES:** □ DESIGN, ______ (BARG)(kPa) □ HYDROTEST, ______ (BARG)(kPa) ▣ RELIEF VALVE(S), SETTING ______ (BARG)(kPa)

▣ **WATER RESERVOIR:** ◇ SIZE: ______ mm DIA X ______ mn HT. ◇ CAPACITY ______ m^3 @Normal Operating Level
◇ RESERVOIR MATERIAL ◇ INTERNAL COATING, TYPE ________
○ LEVEL GAUGE ○ LEVEL SWITCH ○ DRAIN VALVE ○ INSPECTION & CLEAN-OUT OPENINGS

□ **PUMPS (Centrifugal Only)**

	◇ RATED FLOW m^3/h	◇ PRESSURE (BARG)(kPa)	◇ REQ'D kW	◇ DRIVER kW	◇ SPEED RPM	COUPLING REQ'D	MECH. SEAL REQ'D
MAIN	____	____	____	____	____	○	○
AUXILIARY	____	____	____	____	____	○	○

□ PUMP CASING MATERIAL (Ref. 2.12.3.1): MAIN PUMP ________ AUX PUMP ________
○ GUARD(S) REQ. FOR COUPLING(S): ○ MAIN PUMP ○ AUX PUMP ○ GUARD TYPE OR CODE ________
○ AUXILIARY PUMP CONTROL: ○ MANUAL ○ AUTOMATIC ○ ON-OFF-AUTO SEL. SWITCH: ○ BY PURCH. ○ BY MFR.
○ WIRING TO TERMINAL BOX: ○ BY PURCH ○ BY MFR.

○ **COOLING WATER HEAT EXCH:** ○ SHELL & TUBE ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ TEMA C ○ TEMA R (API-660 Data Shts Attached)
○ AIR COOLED EXCHANGER W/AUTO TEMP CONTROL (API-661 Data Sheets Attached)
○ W/BYPASS & TEMP CONTROL VALVE: ○ MANUAL ○ AUTO ○ LOUVERS FOR AIR EXCH.
○ SEE SEPARATE COOLER DATA SHEET FOR DETAILS; SPECIFY % GLYCOL ON BOTH SIDES OF SHELL & TUBE

SYS. COMPONENT SUPP.	MANUFACTURER	MODEL		MANUFACTURER	MODEL
◇ MAIN PUMP	____	____	◇ TEMP CONTROL VALVE(S)	____	____
◇ AUXILIARY PUMP	____	____	◇ TRANSFER VALVE(S)	____	____
◇ MECHANICAL SEALS	____	____	◇ PUMP COUPLING(S)	____	____
◇ ELECTRIC MOTORS	____	____	◇ ____	____	____
◇ STEAM TURBINES	____	____	◇ ____	____	____
◇ ____	____	____	◇ ____	____	____
◇ ____	____	____	◇ ____	____	____

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RECIPROCATING COMPRESSOR DATA SHEET—SI UNITS

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PULSATION SUPPRESSION DEVICES FOR RECIPROCATING COMPRESSORS

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE OF COMRESSION

APPLICABALE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT

FOR/USER ______

SITE/LOCATION ______ AMBIENT TEMPERATURE MIN/MAX ______ / ______ °C

COMPRESSOR SERVICE ______

COMPRESSOR MFG. ______ NUMBER OF COMPRESSORS ______

SUPPRESSOR MFG. ______ MODEL/TYPE ______

NOTE: ○ Ind. Data Comp.'d Purch. ☐ By Compr/Supp. Mfg. w/Proposal ◇ By Mfg(s) after order ☐ By Mfg(s) or Purchaser as Applicable

GENERAL INFORMATION APPLICABLE TO ALL SUPPRESSORS

TOTAL NUMBER OF SERVICES AND/OR STAGES ______

TOTAL NUMBER OF COMPRESSOR CYL. ______ TOTAL NUMBER OF CRANKTHROWS ______ STROKE ______ mm RPM ______

○ ASME CODE STAMP ○ GOVERNMENTAL CODES OF ______ CODE REGULATIONS APPLY

○ OTHER APPLICABLE PRESSURE VESSEL SPEC. OR CODE ______

○ LUBE SERVICE ○ NON-LUBE SERV. ○ NO OIL ALLOWED INTERNALLY DRY TYPE INTERNAL CORROSION COATING ○ YES ○ NO

RADOGRAPHY OF WELDS ○ NONE ○ SPOT ○ 100% ○ IMPACT TEST ○ SPECIAL WELDING REQUIREMENTS

○ SHOP INSPECTION ○ WITNESS HYDROTEST ○ OUTDOOR STORAGE OVER 6 MONTHS ○ SPECIAL PAINT SPEC ______

○ WITNESSED ○ OBSERVED

CYLINDER, GAS, OPERATING, AND SUPPRESSOR DESIGN DATA

	SERVICE ______	STAGE NO. ______
☐ COMPRESSOR MANUFACTURER'S RATED CAPACITY	kg/h ______ m³/h ______ 1.013 BAR @ 0°C	
☐ LINE SIDE OPERATING PRESSURE	INLET, ______ (BAR)(kPa-abs)	DISCHARGE ______ (BAR)(kPa)
☐ OPERATING TEMP. WITHIN SUPPRESSORS	INLET, ______ °C	DISCHARGE, ______ °C
○ ALLOWABLE PRESSURE DROP THROUGH SUPPRESSORS	Δ P ______ (BAR) (kPa-abs) / ______ %	Δ P ______ (BAR) (kPa-abs) / ______ %
	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
○ SUPPRESSOR TAG NUMBER		
○ COMBINATION INLET SUPP SEPARATOR/INTERNALS	○ YES ○ NO / ○ YES ○ NO	/ ○ YES ○ NO
☐ NO. (QTY) OF INLET & DISCH. SUPP. PER STAGE		
○ ALLOWABLE PEAK-PEAK PULSE @ LINE SIDE NOZZLE	(kPa-abs)(BAR) / %	(kPa-abs)(BAR) / %
○ ALLOWABLE PEAK-PEAK PULSE @ CYL FLANGE NOZZLE	(kPa-abs)(BAR) / %	(kPa-abs)(BAR) / %
○ DESIGN FOR FULL VACUUM CAPABILITY	○ YES ○ NO	○ YES ○ NO
○ MIN. REQ'D WORKING PRESSURE & TEMPERATURE NOTE: After design, the actual Mawp & temp are to be determined based on the weakest component and stamped on the vessel, the actual Mawp is to be shown on pg. 14 line 12 and on the U1A Forms.	(BAR) (kPa) ______ @ ______ °C	(BAR) (kPa) ______ @ ______ °C
○ INITIAL SIZING VOL. PER FORMULA OF 3.9.2.2.2 NOTE: This is a Reference	______ m³	______ m³
◇ AS BUILT VOLUME (FT³)	______ m³	______ m³

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PULSATION SUPPRESSION DEVICES FOR RECIPROCATING COMPRESSORS (CONT'D)	SERVICE ______	
THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE OF COMRESSION	STAGE NO. ______	
CONSTRUCTION REQUIREMENTS & DATA	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
○ SUPPRESSOR TAG NUMBER		
○ BASIC MATERIAL REQUIRED, CS, SS, ETC.		
◇ ACTUAL MATERIAL DESIGNATION SHELL/HEAD	/	/
○ SPECIAL HARDNESS LIMITATIONS, Rc ○ YES ○ NO	SHELL & HEADS WELDS	SHELL & HEADS WELDS
▣ CORROSION ALLOWANCE, mm ○ REQUIRED	mm	mm
◇ WALL THICKNESS, mm SHELL/HEAD	mm / mm	mm / mm
□ NOM. SHELL DIA X OVERALL LGTH. (mm/m³)	x mm / m³	x mm / m³
□ PIPE OR ROLLED PLATE CONSTRUCTION	□ PIPE □ ROLLED PLATE	□ PIPE □ ROLLED PLATE
◇ ACT. MAX. ALLOW. WORKING PRESS. AND TEMPERATURE	(BAR) (kPa-abs) @ °C	(BAR) (kPa-abs) @ °C
○ MINIMUM DESIGN METAL TEMP (2.14.8.1)	°C	°C
○ INLET SUPPRESSOR TO BE SAME MAWP AS DISCHARGE SUPPRESSOR	○ YES ○ NO	
◇ MAX. EXPECTED PRESSURE DROP(Δ P, %) LINE PRESS	Δ P (BAR) (kPa-abs) / %	Δ P (BAR) (kPa-abs) / %
◇ WEIGHT, (EACH)	kg	kg
○ INSUL. NUTS & ALLOW. FOR INSULATION REQUIRED (✓)		
◇ EXPECTED P-P PULSE @ LINE SIDE/CYL FLG, % LINE PRESS BASED ON FINAL SUPPRESSOR DESIGN	% / %	% / %
▣ SUPPORTS, TYPE/QUANTITY		
CONNECTION REQUIREMENTS & DATA		
○ LINE SIDE FLANGE, SIZE/RATING/TYPE		
○ COMP CYL FLANGE(S), QTY/SIZE/RATING/FACING/TYPE		
○ FLANGE FINISH, ○ PER 3.9.3.15 > 125 <250 ○ SPECIAL (SPECIFY) ○ PER ANSI 16.5		
○ INSPECTION OPENINGS REQUIRED	○ YES ○ NO ○ BLINDED	○ YES ○ NO ○ BLINDED
○ SPEC. QTY, SIZE, /FLG TYPE & RATING		
◇ * QTY, SIZE, /FLG TYPE & RATING		
○ VENT CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
○ SPEC. QTY, SIZE, /FLG TYPE & RATING		
◇ * QTY, SIZE, /FLG TYPE & RATING		
○ DRAIN CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
○ SPEC. QTY, SIZE, /FLG TYPE & RATING		
◇ * QTY, SIZE, /FLG TYPE & RATING		
○ PRESSURE CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
○ SPEC. QTY, SIZE, /FLG TYPE & RATING		
◇ * QTY, SIZE, /FLG TYPE & RATING		
○ TEMPERATURE CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
○ SPEC. QTY, SIZE, /FLG TYPE & RATING ○ CYL NOZZLE ○ MAIN BODY		
◇ * QTY, SIZE, /FLG TYPE & RATING		
OTHER DATA AND NOTES		
◇ COMPRESSOR MFG'S SUPP. OUTLINE OR DRAWING NO.		
◇ SUPP. MFG'S OUTLINE OR DRAWING NO.		
NOTES* = AS BUILT		

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☐ INSTRUMENTATION

PURCHASER TO FILL IN (☐○○) AFTER COMMODITY TO INDICATE: ☐ BY COMPR. MFG ○ BY PURCHASER ○ BY OTHERS

INSTRUMENT & CONTROL ○ ONE FOR EA. UNIT ○ ONE COMMON TO ALL UNITS
PANEL (☐○○): ○ MACHINE MT'ED ○ FREE STANDING (OFF UNIT) ○ LOCAL ○ REMOTE ○ OUTDOORS
○ PNEUMATIC ○ ELEC. ○ ELECTRONIC ○ HYDRAULIC ○ PROGRAMMABLE CONTL'R
○ NEMA 7 CLASS ______, GROUP ______, DIVISION ______ ○ INTRINSINCALLY SAFE
○ I/S BARRIERS (☐○○)
○ NEMA 4, WATERTIGHT & DUSTTIGHT ○ PURGED TO NFPA 496 TYPE ○ X ○ Y ○ Z
○ OTHER NEMA ______ LOW PURGE PRESS. ○ ALARM ○ SHUTDOWN
○ VIB. ISOLATORS ○ STRIP HEATERS ○ PURGE CONN. ○ EXTRA CUTOUTS
○ ANNUNCIATOR W/FIRST-OUT INDICATION LOCATED ON CONTROL PANEL
○ PURCHASER'S CONN. BROUGHT OUT TO TERMINAL BOX BY VENDOR

ADDITIONAL PANEL REMARKS:

○ INSTRUMENTATION SUITABLE FOR: ○ INDOORS ○ OUTDOORS ○ OTHER ______

○ PREFERRED INSTRUMENT SUPPLIERS, (TO BE COMPLETED BY PURCHASER), OTHERWISE MFR'S STANDARD APPLIES

PRESSURE GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
TEMPERATURE GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
LIQUID LEVEL GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
DIFF. PRESSURE GAUGES	MFR ______	SIZE & TYPE ______	MTL ______
PRESS. TRANSMITTERS	MFR ______	SIZE & TYPE ______	MTL ______
LIQUID LEV. TRANSMITTER	MFR ______	SIZE & TYPE ______	MTL ______
PRESSURE SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
TEMPERATURE SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
LIQUID LEVEL SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
DIFF. PRESSURE SWITCHES	MFR ______	SIZE & TYPE ______	MTL ______
CONTROL VALVES	MFR ______	SIZE & TYPE ______	MTL ______
PRESSURE SAFETY VALVES	MFR ______	SIZE & TYPE ______	MTL ______
SIGHT FLOW INDICATORS	MFR ______	SIZE & TYPE ______	MTL ______
VIBRATION MONITORS & EQUIP.	MFR ______	SIZE & TYPE ______	MTL ______
THERMOCOUPLES	MFR ______	SIZE & TYPE ______	MTL ______
RTD'S	MFR ______	SIZE & TYPE ______	MTL ______
SOLENOID VALVES	MFR ______	SIZE & TYPE ______	MTL ______
ANNUNCIATOR	MFR ______	MODEL & (QTY SPARE POINTS) ______	(______)
PROGRAMMABLE CONTROLLER	MFR ______	SIZE & TYPE ______	MTL ______
______	MFR ______	SIZE & TYPE ______	MTL ______
______	MFR ______	SIZE & TYPE ______	MTL ______

○ PRESSURE GAUGE REQUIREMENTS ○ LIQUID FILLED PRESSURE GAUGES: ○ YES ○ NO

FUNCTION	LOCALLY MOUNTED	PANEL MOUNTED		LOCALLY MOUNTED	PANEL MOUNTED
LUBE OIL MAIN PUMP DISCHARGE	(☐○○)	(☐○○)	PROCESS GAS: INLET PRESS.		
LUBE OIL AUX PUMP DISCHARGE	(☐○○)	(☐○○)	@ EA. STAGE	(☐○○)	(☐○○)
LUBE OIL PRESS. AT FRAME HEADER	(☐○○)	(☐○○)	DISCH. PRESS.		
LUBE OIL FILTER Δ P	(☐○○)	(☐○○)	@ EA. STAGE	(☐○○)	(☐○○)
COOLING WATER INLET HEADER	(☐○○)	(☐○○)	______	(☐○○)	(☐○○)
______	(☐○○)	(☐○○)	______	(☐○○)	(☐○○)
______	(☐○○)	(☐○○)	______	(☐○○)	(☐○○)

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INSTRUMENTATION (CONT'D)

TEMPERATURE MEASUREMENT REQUIREMENTS

FUNCTION	LOCALLY MNT'D	PANEL MNT'D	GAUGE W/ CAPILLARY	THERMO-COUPLE SYS	RTD SYS	I/S SYS
LUBE OIL ○ INLET TO ○ OUT OF FRAME	(□ ○ ○)	(□ ○ ○)	○	○	○	○
LUBE OIL ○ INLET TO ○ OUT OF COOLER	(□ ○ ○)	(□ ○ ○)	○	○	○	○
MAIN JRNL BEARINGS (THERMOCOUPLES OR RTD'S ONLY)	(□ ○ ○)	(□ ○ ○)	○	○	○	○
MOTOR BEARING(S) (THERMOCOUPLES OR RTD'S ONLY)	(□ ○ ○)	(□ ○ ○)	○	○	○	○
COOLING WATER HEADER: ○ INLET ○ OUTLET	(□ ○ ○)	(□ ○ ○)	○	○	○	○
CYL. COOLING WATER: ○ INLET ○ OUTLET ○ EACH CYL	(□ ○ ○)	(□ ○ ○)	○	○	○	○
PROCESS GAS: ○ INLET ○ DISCHARGE ○ EACH CYL	(□ ○ ○)	(□ ○ ○)	○	○	○	○
INTERCOOLER(S): ○ INLET ○ GAS ○ WATER	(□ ○ ○)	(□ ○ ○)	○	○	○	○
○ INLET ○ GAS ○ WATER	(□ ○ ○)	(□ ○ ○)	○	○	○	○
AFTERCOOLER: ○ INLET ○ GAS ○ WATER	(□ ○ ○)	(□ ○ ○)	○	○	○	○
○ INLET ○ GAS ○ WATER	(□ ○ ○)	(□ ○ ○)	○	○	○	○
COOLING WATER ○ INLET ○ OUTLET/COOLED PKG CASE(S)	(□ ○ ○)	(□ ○ ○)	○	○	○	○
PRESS. PKG CASE, CYL PIST ROD (THERMOCOUPLES OR RTD' ONLY)	(□ ○ ○)	(□ ○ ○)		○	○	○
COMPRESSOR VALVES ○ SUCT ○ DISCH TC'S OR RTD'S ONLY)	(□ ○ ○)	(□ ○ ○)	○	○	○	○
______	□ ○ ○	(□ ○ ○)	○	(○)	○	○
______	(□ ○ ○)	(□ ○ ○)	○	○	○	○

ALARM & SHUTDOWN SWITCH REQ'MTS NOTE: ALARM & SHUTDOWN SWITCHES SHALL BE INDIVIDUALLY SEPARATE

FUNCTION	ALARM	SHUT-DOWN	ANNUNCIATION POINTS: ALARM IN PNL BY MFR	ALARM IN CTL ROOM PNL OTHERS	SHUTDOWN IN PNL BY MFR	SHUTDOWN IN CTL ROOM PNL OTHERS	TOTAL NO. OF POINTS
LOW LUBE OIL PRESS. @ BEARING HEADER	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HIGH LUBE OIL Δ P ACROSS FILTER	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
LOW LUBE OIL LEVEL, FRAME	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
AUX LUBE OIL PUMP, FAIL TO START	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
CYL LUBE SYSTEM PROTECTION	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
COMPR. VIBRATION, SHUTDOWN ONLY					○	○	______
VIBRATION, W/ CONTINUOUS MONITORING	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
ROD DROP DETECTOR, CONTACT TYPE (1/CYL)	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
ROD DROP PROXIMITY PROBES (I/CYL)	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
OIL TEMP OUT OF FRAME	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HIGH GAS DISCH. TEMP. EACH CYLINDER	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HIGH JACKET WATER TEMP., EA. CYL.	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
LOW SUCTION PRESS., FIRST STG INLET	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HI DISCH. PRESSURE ○ FINAL ○ EA STG	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HI CYL. GAS Δ P, EACH STAGE	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HI LIQ. LEV., EA. MOISTURE SEPARATOR	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
LOW PURGE GAS PRESS, DISTANCE PIECE(S)	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
HI X-HD PIN TEMP	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
PRESS PKG CASE (PISTON ROD TEMP)	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
______	(□ ○ ○)	(□ ○ ○)	○	○	○	○	______
					TOTAL NUMBER OF ANNUNCIATION POINTS		______

SWITCH CONTACT OPERATION — NOTE: EACH SWITCH SHALL BE MINIMUM SPDT ARRANGEMENT

ALARM CONTACTS SHALL: ○ OPEN (DE-ENERGIZED) TO SOUND ALARM & BE ENERGIZED WHEN COMPRESSOR IS IN OPERATION
○ CLOSE (ENERGIZE) TO SOUND ALARM & BE DE-ENERGIZED WHEN COMPRESSOR IS IN OPERATION

SHUTDOWN CONTACTS SHALL: ○ OPEN (DE-ENERGIZED) TO SHUTDOWN & BE ENERGIZED WHEN COMPRESSOR IS IN OPERATION
○ CLOSE (ENERGIZE) TO SHUTDOWN & BE DE-ENERGIZED WHEN COMPRESSOR IS IN OPERATION

REF: 3.6.5.1 FOR MINIMUM RECOMMENDED PROTECTION REQUIREMENTS

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☐ INSTRUMENTATION (CONT'D)

○ MISCELLANEOUS INSTRUMENTATION — ○ INTERCOOLER(S) ○ AFTERCLR ○ OIL CLR ○ H_2O CLR

SIGHT FLOW IND. (COOLING H_2O ONLY)	(☐ ○ ○) FOR	○ CYL JACKET WATER ○ ROD PRESS. PACKING CASES
PNEUMATIC PRESSURE TRANSMITTERS	(☐ ○ ○) FOR:	
PRESSURE TRANSMITTERS (ELEC. OUTP.)	(☐ ○ ○) FOR:	
PNEUMATIC LEVEL TRANSMITTERS	(☐ ○ ○)	
ALARM HORN & ACKN'LMT TEST BUTTON	(☐ ○ ○)	
CONDUIT & WIRING W/JUNCT. BOXES (CONSOLES)	(☐ ○ ○)	
TEST VALVES	(☐ ○ ○) FOR:	
DRAIN VALVES	(☐ ○ ○) FOR:	
GAUGE GLASS(ES)	(☐ ○ ○) FOR:	
TACHOMETER	(☐ ○ ○)	______ SPEED RANGE ______ TO ______ RPM
CRANKSHAFT KEY PHASER AND TRANSDUCER	(☐ ○ ○) FOR:	
	(☐ ○ ○)	
	(☐ ○ ○)	

○ SEPARATE LUBE OIL CONSOLE INSTRUMENTATION: PURCH. TO LIST REQ'MTS IN ADDITION TO ANY ABOVE REQ'MTS

	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	

○ SEPARATE COOLING WATER CONSOLE INSTRUMENT: PURCH. TO LIST REQ'MTS IN ADDITION TO ANY ABOVE REQ'MTS

	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	
	(☐ ○ ○)	

☐ RELIEF VALVES

LOCATION	BY	MANUFACTURER	TYPE	◇ SIZE	◇ SETTING
	(☐ ○ ○)				
	(☐ ○ ○)				
	(☐ ○ ○)				
	(☐ ○ ○)				
	(☐ ○ ○)				
	(☐ ○ ○)				
	(☐ ○ ○)				
	(☐ ○ ○)				
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NOTES: SEE MOTOR DATA SHEET FOR ADDITIONAL MOTOR INSTRUMENTATION REQUIREMENTS
FOR TURBINE DRIVERS USE APPLICABLE API DATA SHEETS
FOR GEAR REDUCERS USE APPLICABLE API DATA SHEETS
ELECTRICAL & INSTRUMENTATION CONNECTIONS SHALL BE MADE DIRECTLY BY THE PURCHASER TO INDIVIDUAL INSTRUMENTS ON THE COMPRESSOR

ADDITIONAL INSTRUMENTATION REMARKS/SPECIAL REQUIREMENTS:

APPENDIX B—REQUIRED CAPACITY, MANUFACTURER'S RATED CAPACITY, AND NO NEGATIVE TOLERANCE

This appendix discusses capacity sizing of reciprocating compressors and the intent of the term *no negative tolerance* (NNT) as used in this standard to apply to the *required capacity* of reciprocating process compressors (see 2.1.12, 1.4.11, 1.4.20, and 1.4.30).

The term *required capacity, rated for process* (see preceding references) is the minimum capacity required to meet the process conditions with no negative tolerance permitted. The purchaser will complete the data sheets (Appendix A) with a required capacity when the capacity must never be less than that specified. In such a case, the sizing of the compressor must take into account the manufacturer's standard tolerances so that the resulting capacity will never be less than the required capacity.

The compressor manufacturer's rated capacity is that capacity to which the compressor is sized. The acceptable standard reciprocating compressor industry tolerance of ±3 percent is applicable to both the capacity and power at the compressor shaft. Because of this tolerance on capacity, the manufacturer will increase the required capacity by 3 percent prior to sizing the compressor. (The required capacity divided by 0.97 equals the manufacturer's rated capacity). If NNT is not a purchaser's requirement, the purchaser should complete only the manufacturer's rated capacity on the data sheet.

As used in the data sheets (Appendix A) under the manufacturer's rated capacity, *Total kilowatts (horsepower) @ the compressor shaft* is intended to mean the power required at the compressor input shaft as it would be measured by a brake. *Total kilowatts (horsepower) including v-belt and gear losses* is the total power at the compressor shaft plus all losses in the drive system and is used for selecting the driver.

The concept of no positive tolerance on power is omitted from this standard on the basis of the following conditions:

a. The tolerance of the manufacturer's certified shaft power is ±3 percent, and is calculated on the basis of the manufacturer's rated capacity.
b. Using the manufacturer's rated capacity and corresponding power, the proper relationship of power to unit capacity (for example kilowatts per hundred cubic meters per hour or brake horsepower per hundred cubic feet per minute) exists and will agree with calculations.
c. The driver nameplate power should be selected to be a minimum of 110 percent (for electric motors) or 120 percent (for turbines) of the greatest total power required, including losses, for any of the given operating conditions. The greatest total power should be based on the ±3 percent portion of the manufacturer's tolerance (see 3.1.2.2 and 3.1.3.1).

APPENDIX C—PISTON ROD RUNOUT IN HORIZONTAL RECIPROCATING COMPRESSORS

C.1 Scope

This appendix describes a procedure that can be used to determine expected piston rod runout in horizontal reciprocating compressors with traditional crosshead/piston rod/piston construction. Piston rod runout, using precision dial indicators, is a measurement criterion used to determine piston rod running alignment variations in both horizontal and vertical positions relative to cylinder and crosshead alignment. While other alignment methods, such as optical, laser, or wire, may be used to determine initial assembly alignment, use of dial indicators on the piston rod verifies alignment by determining the true running variation of the rod as it passes through its stroke. Once factory alignment has been verified by correct rod runout measurement, and so recorded, it is a convenient field method of verifying alignment after installation and routine maintenance.

Manufacturers with other types of compressors, having unique or proprietary construction, may require different methods for calculating expected cold vertical rod runout.

C.2 Definition

Piston rod runout in this appendix is defined as the measurement variation in millimeters [thousandths of an inch] in the reading of fixed position dial indicators in contact with the rod as the rod is moved slowly through its stroke by manual bar-over. Horizontal runout is taken on the side of the rod to determine horizontal variations, while vertical runout is taken on the top of the rod to determine vertical variations due to rod sag and the difference in crosshead and piston running clearances.

C.3 Maximum Allowable Runout

C.3.1 Acceptable limits of rod runout and shop test requirements and records are discussed in 2.6.2.1 in the text.

C.3.2 The maximum allowable horizontal runout at any side position of the dial indicators shall be zero, plus or minus 0.00015 millimeter per millimeter (0.00015 inch per inch) of stroke, up to a maximum of 0.064 millimeter (0.0025 inch).

C.3.3 The maximum allowable vertical runout at any top position of the dial indicators shall be the calculated runout, in millimeters (thousandths of an inch), at that specific dial indicator position based on length of stroke, length of rod, rod sag, and the difference between the crosshead and cylinder running clearances, plus or minus 0.00015 millimeter per millimeter (0.00015 inch per inch) of stroke. See remainder of appendix for an example of vertical runout calculations based on a suggested procedure.

C.3.4 The permissible limits of 0.00015 millimeter per millimeter (0.00015 inch per inch) of stroke allow for geometric and fit tolerances of all parts that may contribute to slight parallel offset and angular misalignment.

C.4 General

C.4.1 Piston rod runout is always an inspection requirement during the shop assembly of a new compressor to verify alignment. It is almost always a purchaser's witness test requirement of alignment to determine that geometric and fit dimensions of all parts are correct, and that these parts have been properly assembled with parallel offset and/or angular misalignment within the established runout limits. In addition, as part of new compressor field installations, rod runout is always checked and verified against shop readings. It is also a requirement of normal compressor maintenance, especially after overhaul and reassembly of the cylinders.

C.4.2 Runout must be checked in both horizontal and vertical directions. It is best to check runout at both the crosshead and at the cylinder to verify that the crosshead and piston are running true in the crosshead guide and cylinder respectively.

C.4.3 While rod runout can be used to verify alignment, it should not be used to align compressor cylinders during the original assembly of the machine unless it has been established that all assembled components and fits are within the tolerances required for size, squareness, parallelism, and concentricity.

C.4.4 After assembly and in the field, compressor cylinders, distance pieces, and crosshead guides should never be forced into positions of harmful stresses in an attempt to satisfy rod runout requirements.

C.4.5 Due to the piston rod length, vertical runout must include the effect of rod sag when type B, C, and D distance pieces are used. In the case of older units, or new units with no distance piece, or with the very short type A distance piece, rod sag may be so minimal that it can be ignored and the basics of Figures C-1 and C-2 can be used to compute expected vertical rod runout for perfect alignment.

C.5 Procedure

C.5.1 Rod runout should ideally be checked at both the crosshead end and at the piston end of the rod. For this purpose one dial indicator is placed as close as possible to the crosshead and the other is placed as close as possible to the piston, the latter position being in the distance piece next to the rod pressure packing case as shown in Figure C-5A. This is about as close to the piston and cylinder as typically attainable. Normally checks are made in the cold condition, that is, when all parts are at ambient temperature. Factory readings are to be recorded on a "rod runout table" similar to that illustrated at the end of this appendix (see Table C-1), and provided as part of the manual for rod runout reference at time of installation.

C.5.2 Dial indicators for vertical runout should be placed on top of the rod at the 12 o'clock position as shown in Figures C-3, C-4, and C-5A. For horizontal runout, dial indicators should be placed on the "drive side" (in other words, the side toward the driver) of the rod at the 3 o'clock or 9 o'clock position depending on which throw is being measured. For accurate readings, dial indicators must be perpendicular to the rod at these positions.

C.5.3 For correct vertical rod runout calculations, it is important to use actual measured running clearances for the cylinder and crosshead, as well as the actual measured dimensions of the dial indicator locations along the top of the piston rod. Correct rod lengths as required by Figure C-5A are also important.

C.5.4 Rod runout should always be measured starting with the rod at the extreme end of the stroke, with the piston at the crank end of the cylinder. The dial indicators should be zeroed. Manual bar-over should be such that the connecting rod runs over (that is, over the top on the outstroke) as the crosshead, piston rod, and piston are stroked slowly outward toward the end of the stroke at the head end of the cylinder. Dial indicator readings are observed during the stroke and recorded at the end of the stroke. If this method, and the dial indicator positions noted in C.5.2 are used as the standard measurement procedure, then field runout readings can be properly compared and evaluated with factory runout readings provided in Table C-1.

C.5.5 The dimensions shown in Figures C-1 through C-4, and used in Figure C-5B for the calculation example, were selected for convenience in illustrating basic runout geometry and principles. Dimensions for actual compressors may vary greatly from the illustration dimensions, while some may be close or identical. Since vertical rod runout will vary according to stroke, rod length, rod sag, and the difference in running clearances between the crosshead and cylinder, different compressors with different cylinder configurations may have significantly different vertical runout readings for conditions of perfect alignment.

C.5.6 Squareness of rod threads in relation to piston rod nut threads and face and in relation to crosshead threads and face is a critical factor affecting both horizontal and vertical runout. As a check for squareness at the interface of the crosshead and piston rod, both horizontal and vertical runout should be checked first with the crosshead nut loose and then tight.

C.5.7 Excessive rod runout is corrected by realignment and/or squaring up some or all components involved. These may include cylinders, liners, heads, distance pieces, crossheads and crosshead guides, and rods and pistons. Crosshead threads and face, piston rod nut threads and face, and piston rod threads may have to be checked and corrected for perpendicularity. Certain conditions of excessive rod runout at the packing case can further be evaluated by placing an dial indicator on the rod in the cylinder through a crankend valve port to verify full length liner concentricity with the cylinder bore and/or cylinder crank end face squareness with the bore. With a dial indicator in the cylinder, full stroke runout cannot be taken since the dial indicator takes up some of the space between the crankend head and the piston. However, the available stroke is sufficient to get a suitable reading to determine alignment status.

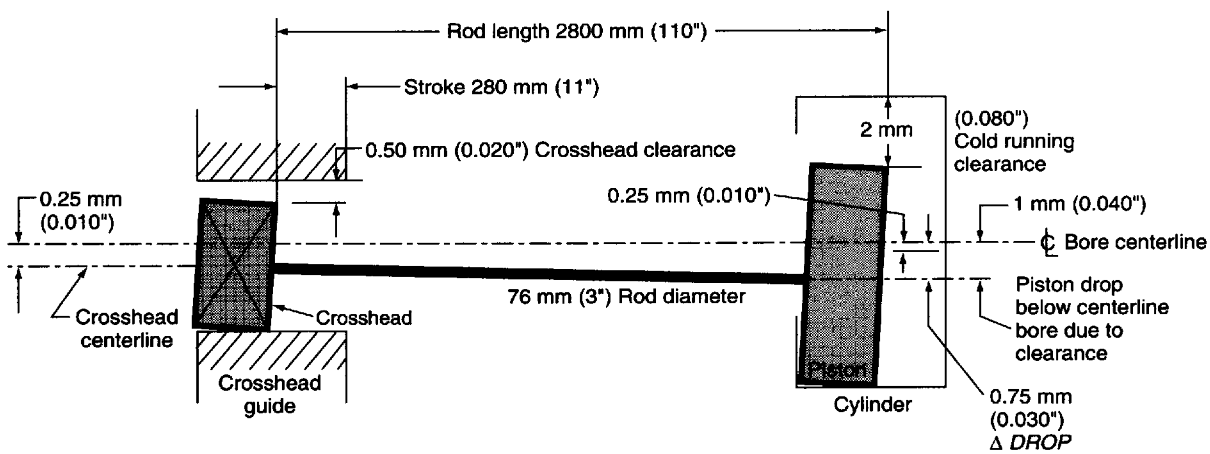


Figure C-1—Basic Geometry of Cold Vertical Rod Runout

C.6 Horizontal Runout

Horizontal runout readings can be used as a direct indication of the horizontal alignment from the crosshead through the distance pieces to the cylinder. No calculations are necessary, as horizontal runout should be within the zero limits regardless of whether the unit is cold or hot, or of the axial location of the dial indicator along the side of the rod. It is measured by placing dial indicators on the side of the rod as close as possible to the crosshead and the pressure packing case at the locations noted in C.5.2, and shown in Figure C-5A. For perfect alignment, the dial indicators should read zero as the rod is moved slowly through the entire length of the stroke during manual bar-over. The best indication of perfect horizontal alignment is when horizontal rod runout measures zero with dial indicators set at both the crosshead end and the piston end of the rod, in other words, as close to the packing case as possible. A tolerance of ±0.00015 millimeters per millimeter (±0.00015 inch per inch) of stroke is permissible up to a maximum of 0.064 millimeter (0.0025 inch).

C.7 Vertical Runout

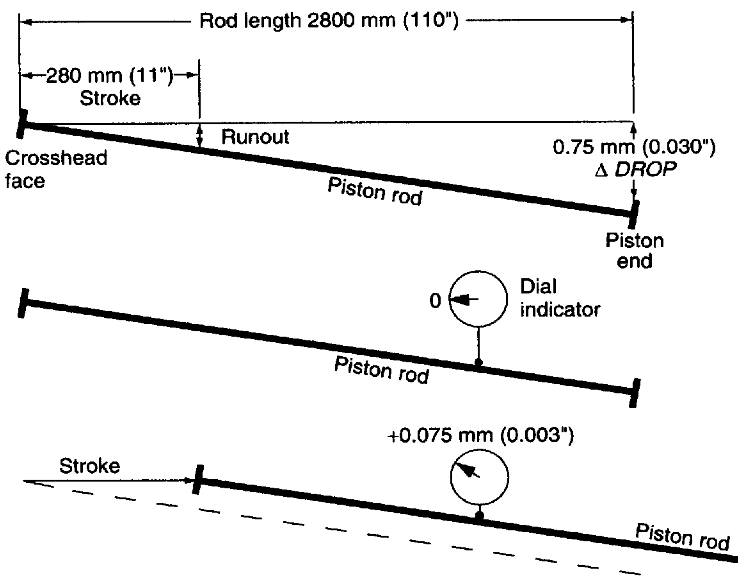
C.7.1 COLD RUNOUT

Cold vertical runout readings other than zero are not necessarily an indication of misalignment. When all components are perfectly aligned, the normal cold vertical rod runout is the result of the difference between the cold running clearance of the piston in the bore and that of the crosshead in the crosshead guide, plus the effect of normal rod sag, the length of the stroke, the length of the rod, and the location of the dial indicators along the top of the rod. It is, therefore, important that the actual running clearances for the cylinder and crosshead are used for the calculations, as well as the rod lengths and actual dial indicator locations shown in Figure C-5A.

C.7.2 BASIC GEOMETRY

The basic geometry is illustrated in Figures C-1 and C-2. Piston and crosshead centerlines lie below the perfect alignment centerline by one half of the running clearances. In cylinders where the running clearance is greater (or less) than the crosshead running clearance, the piston will lie below (or above) the crosshead centerline by one half of the difference in the cold running clearances. The result is basic vertical rod runout that is normally something other than zero for perfect alignment. This one-half clearance difference is referred to as the *differential drop* (Δ *DROP*). The basic geometry closely approximates a right triangle condition.

Basic ideal vertical runout through the stroke length, as shown in Figure C-2, is determined by the normal running clearances and resulting Δ *DROP*, the rod length, and the stroke. Assuming an ideal straight-rod situation, in other words, without sag, basic cold vertical runout for perfect alignment can be calculated with sufficient accuracy using proportional right-triangle equations as shown in Figure C-2, when these values are known. The principle can also be used to calculate Δ *DROP* at any point on the rod, which is



Vertical rod runout at perfect alignment conditions, with no rod sag, closely approximates a proportional right triangle relationship where

$$\frac{\textbf{Stroke}}{\textbf{Rod Length}} = \frac{\textbf{Runout}}{\Delta\ \textbf{\textit{DROP}}}$$

$$\therefore \textbf{Runout} = \frac{\textbf{Stroke}}{\textbf{Rod Length}} \times \Delta\ \textbf{\textit{DROP}}$$

Δ *DROP* = 1/2 difference in running clearance of piston and crosshead

$$\therefore \textbf{Runout} = \frac{11}{110} \times 0.030$$

= 0.003 inches for this example

$$\textbf{Or} = \frac{280}{2800} \times 0.75$$

= 0.075 mm for this example

Figure C-2—Vertical Runout Geometric Relationships Based on No Rod Sag

Table C-1

ROD RUNOUT TABLE

Contractor/User ____________ Job No. ____________ Item No. ____________

Purchase Order No. ____________ Site/Location ____________ Date ____________

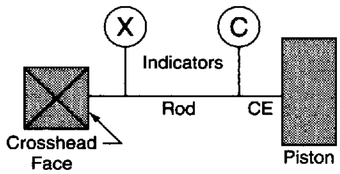
Compressor Mfgr. ____________ Type/Model ____________ Ser. No. ____________

Piston Rod Runout Data: Throw No. ________ Stage ________ Cyl. Bore Dia. ________ Stroke ________

Cylinder Bore Running Clearance ____________ Crosshead Running Clearance ____________

Ref: Rod Dia. ________ Rod Length (Crosshead Face to CE Piston Face) ________ Rod Sag ________

Indicator Positions (Piston at CE) From Crosshead Face To: X ________ C ________



	EXPECTED / ACTUAL ROD RUNOUT				
	Allowable Limits @ X Expected	Measured Values @ X **Actual**	Allowable Limits @ C Expected	Measured Values @ C **Actual**	Inspector & Date
Cold (Before Run)					
Vertical (Top, Nut Loose)					
Horizontal (Drive Side, Nut Loose)					
Vertical (Top, Nut Tight)					
Horizontal (Drive Side, Nut Tight)					
Hot (After run) ❑ Unit Not Shop Run					
Vertical (Top)					
Horizontal (Drive Side)					
Cold (Retake) ❑ Required ❑ Not Required					
Vertical (Top)					
Horizontal (Drive Side)					

necessary to calculate vertical rod runout at specific dial indicator locations when combining Δ *DROP* with rod sag as shown in Figures C-3 and C-4.

C.7.3 ROD SAG

Since all horizontal rods sag, especially those used in Types B, C, and D distance pieces, it is necessary to incorporate the effects of deflection based on rod length, rod diameter, rod weight, and rod material into the vertical runout calculations. When vertical rod runout readings are taken at several positions along the entire length of the piston rod, the readings will generally indicate that sag for a long rod attached to a crosshead and to a piston, when installed in a compressor assembly with precise geometric parts that have been proven to be perfectly aligned, will exhibit deflection characteristics similar to that for one end supported (at the crosshead), and one end fixed (at the piston). For these reasons, it is necessary to calculate the expected vertical rod runout at the crosshead end, and at the piston end of the rod based on Figure C-5A. Note that the data *includes both dial indicator positions along the top of the rod.* The combined Δ *DROP* and deflection must be calculated at these dial indicator positions as shown in Figures C-3 and C-4.

As can be seen from Figures C-3 and C-4, rod sag will cause different vertical runout readings at different dial indicator positions along the top of the rod. For conditions of perfect alignment, at the lowest point of sag, runout readings may be nearly zero depending on cylinder clearance (Δ *DROP*), while at the crosshead end, readings should always be positive. Next to the cylinder packing case, readings may be positive, or they may be negative, depending on rod length, sag, and cylinder running clearance (Δ *DROP*). The zero vertical runout position can usually be found by placing the dial indicator along the top of the rod until the lowest point of sag is reached.

When the rod is stroked forward (that is, out toward the head end as noted in C.5.3 and shown in Figures C-3 and C-4), the dial indicator at the crosshead should normally read positive.

C.8 Hot Runout

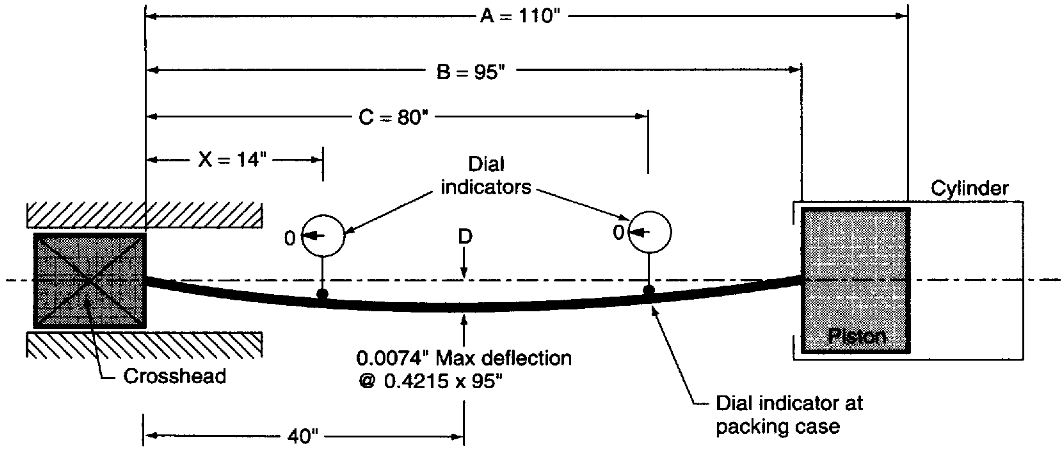
For large cylinders with aluminum pistons and fluorocarbon wear bands, there can be a significant difference between the cold rod runout and the hot runout. This is because of the high thermal expansion rate of the aluminum piston and the fluorocarbon wear bands, which can result in a significant difference in the differential clearance between the piston and the crosshead. On the other hand, there may be operating conditions involving low suction temperatures such that normal operating temperatures may be no greater than the ambient temperature on which the cold vertical runout readings are taken. Expected hot runout can be determined by calculating the expected thermal growth of the cylinders, the pistons, and the rider ring radial thickness. The cylinder running clearance, affecting hot Δ *DROP*, is then adjusted accordingly in the vertical runout calculations.

It is desirable that hot vertical rod runout not exceed 0.00015 millimeter per millimeter (0.00015 inch per inch) of stroke at the packing case. Due to the effects of rod sag, this may not always be attainable under conditions of perfect alignment; and it is necessary to determine whether the value should be positive or negative. Misalignment may be significantly different for a positive reading of 0.042 millimeter (0.00165 inch) [(280 millimeter stroke × 0.00015 (11 inch stroke × 0.00015)] than for a negative reading of -0.042 millimeter (-0.00165 inch). This can be seen from a study of Figure C-5C and the five curves illustrated by Figures C-6 through C-10. Sometimes this requirement can be attained by shim adjustment of the crosshead shoes (see C.9), but a thorough study of cold readings compared to expected results from computer calculations is required to determine what adjustments, if any, are needed, or should be done to obtain the ideal desired vertical runout at operating temperatures. In many cases, where there is considerable sag, it may be better to operate as is than attempt to adjust the vertical runout, particularly if the cylinder and crosshead guide alignments are near perfect.

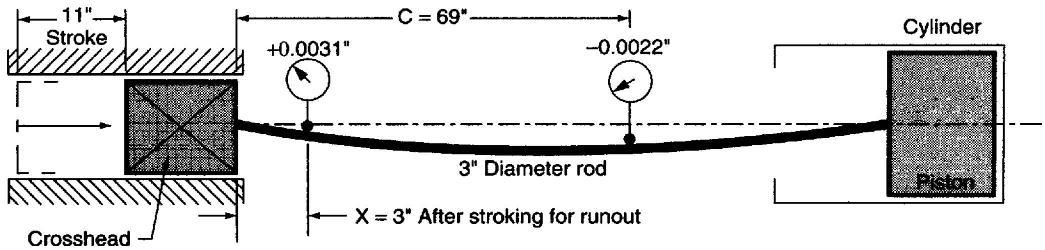
C.9 Vertical Runout Adjustment

If it is believed that some adjustment is necessary to the vertical runout readings, it must first be assured that cylinder alignment and cylinder level are properly set so that the components are free of harmful stresses at operating conditions. If crosshead shim adjustment is then considered necessary by interchanging shims under the crosshead shoes, it should be remembered that taking shims from the bottom shoe and placing them under the top shoe drops the crosshead centerline further below the perfect alignment centerline. This decreases the Δ *DROP* and thus decreases the positive rod runout at the crosshead, but may actually increase negative runout at the packing case due to sag. This is illustrated on Figure C-5C and in the series of five runout curves of Figures C-6 through C-10.

With reference to Figures C-6 and C-9, note that a 0.76 millimeter (0.030 inch) change of shims, that would put the crosshead and piston on the same centerline such that Δ *DROP* = 0.00, changes the runout by only 0.076 millimeter (0.003 inch), that is, the crosshead runout goes to +0.079 millimeter (+0.0031 inch) from +0.155 millimeter (+0.0061 inch), and the runout at the packing case goes to -0.056 millimeter (-0.0022 inch) from +0.020 millimeter (+0.0008 inch). In other words, for this example, rod runout is changed by only 0.0254 millimeter (0.001 inch) for each 0.254 millimeter (0.010 inch) of shims removed from the bottom shoe in an attempt to lower the crosshead closer to the centerline of the cylinder. Because rod length and rod di-



Crosshead and cylinder clearances identical, Δ ***DROP*** = 0



Note: This example is based on US customary units.

Initial deflection calculation: Crosshead end supported (free end) – piston end fixed. Max deflection occurs at 0.4215 x rod length 95".

Rod diameter = 3"
Density = 0.283 lb/in^3 (steel)
Modulus of elasticity, E = 30 x 10^6 psi
Rod length B = 95"

Total weight = 190 lb
Moment of inertia, I = 3.9761 in^4
Rod length C at cylinder indicator position = 80"

Max D = $$\frac{1}{184.65}\left(\frac{WB^3}{EI}\right) = \frac{1}{184.65}\left(\frac{190 \times 95^3}{30 \times 10^6 \times 3.9761}\right) = 0.0074\text{" at 40.04" from free end}$$

Deflection at any point C on the rod $$= \frac{1}{48} \bullet \frac{W}{EIB}\left(3BC^3 - 2C^4 - B^3C\right)$$

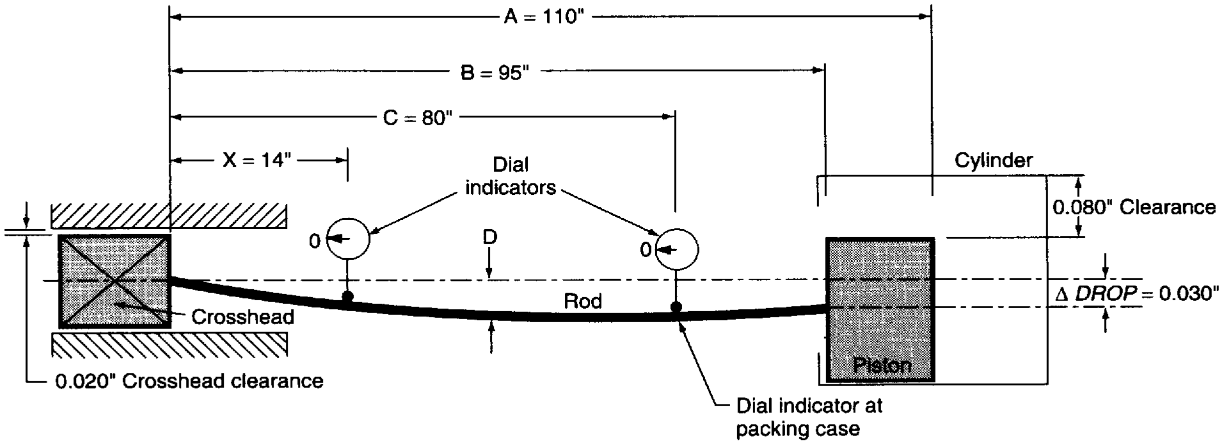
∴ **Deflection at indicator location C = 80"** $$= \frac{1}{48} \bullet \frac{190}{EI \bullet 95}\left(3 \bullet 95 \bullet 80^3 - 2 \bullet 80^4 - 95^3 \bullet 80\right)$$
$$= 0.02083 \bullet 1.6767 \times 10^{-8}\,(-4{,}590{,}000) = -0.0016\text{"}$$

Deflection at C = 69" (80" minus stroke) $$= 0.02083 \bullet 1.6767 \times 10^{-8}\left(3 \bullet 95 \bullet 69^3 - 2 \bullet 69^4 - 95^3 \bullet 69\right)$$
$$= 0.02083 \bullet 1.6767 \times 10^{-8}\,(-10{,}868{,}052) = -0.0038\text{"}$$

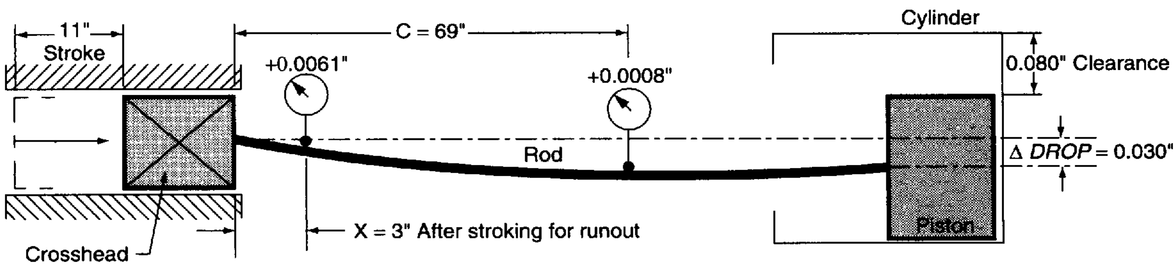
∴ **Rod runout at packing case** $= 0.0016\text{"} - 0.0038\text{"} = -0.0022\text{"}$

The same calculations for the indicator location of 14" from the crosshead and at 3" after stroking 11" gives a value of +0.0031 for rod runout at the crosshead.

Figure C-3—Rod Runout Attributable to Piston Rod Sag With Δ *DROP* = 0



Crosshead clearance = 0.020", cylinder clearance = 0.080", Δ *DROP* = 0.030"



Note: This example is based on US customary units.
D = Maximum sag

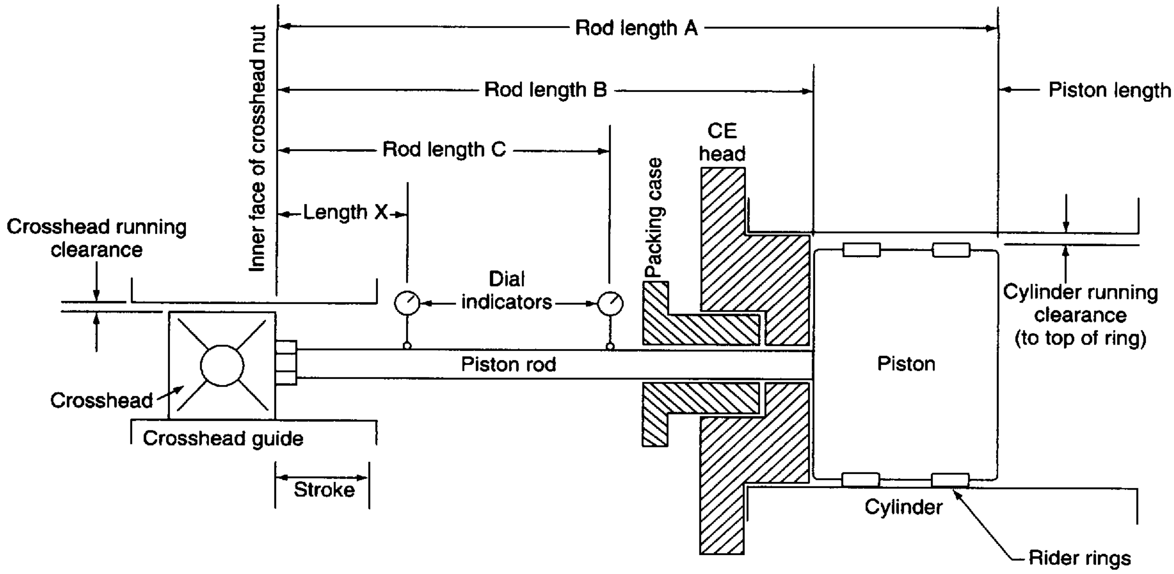
To calculate rod runout at cylinder running clearances that are different than the crosshead running clearance, combine the deflection runout shown for Figure C-3 with incremental Δ *DROPS* at indicator positions based on Figure C-2. These calculations can be quite extensive and are best done by a suitable computer program. A printout of an example of one such program is illustrated in Figure C-5C using the calculation data shown on Figure C-5B. This particular program calculates the runout values at increments of 1" rod lengths, combines the values, calculates the expected runout figures at the indicator positions, and plots the curves shown in Figures C-6 through C-10.

As shown on the computer printout sheet Figure C-5C and the curve of Figure C-6, the combined rod runout would be +0.0008" at the packing case indicator location, and +0.0061" at the crosshead indicator location with a cylinder running clearance of 0.080", and a crosshead running clearance of 0.020" for a Δ *DROP* of 0.030". The effect of decreasing cylinder running clearance by 0.020" increments is also shown on Figure C-5C and the curves of Figure C-7 through C-10. As mentioned in Paragraph C-9, this is equivalent to removing 0.010" of shims from the bottom shoe of the crosshead, changing the Δ *DROP* by 0.010" increments. Note that each 0.010" shim removal changes the rod runout by only about 0.001" for this example.

Figure C-4—Rod Runout Attributable to Piston Rod Sag With Δ *DROP* > 0

ameter, which affect sag, and cylinder size, which affects running clearance, can significantly affect vertical runout, every compressor cylinder assembly must be fully evaluated for expected vertical runout based on perfect alignment conditions. If crosshead shims are shifted in an attempt to adjust vertical runout, it is important that the crosshead always be installed with the "top" side up following removal for maintenance.

These illustrations also demonstrate the importance of using the actual measured running clearances of the cylinder and crosshead when calculating and evaluating vertical rod runout since a change of cylinder running clearance will affect Δ *DROP* which in turn affects vertical runout. For some combinations of cylinder size, rod length, and stroke, the cylinder clearance will have a greater effect on vertical rod runout than other combinations. As the basics illustrate in Figures C-1 and



- ☐ Throw number ____________
- ☐ Stage ____________
- ☐ Cylinder bore diameter ____________
- ● Cylinder running clearance ____________
- ● Crosshead running clearance ____________
- ● Stroke ____________
- ● Rod diameter ____________
- ● Rod length A ____________
- ● Rod length B ____________
- ● Rod length C Indicator Position ____________
- ● Rod length X Indicator Position ____________
- ☐ Rod material ____________
- ● Material density, kg/m³ (lb/in³) ____________
- ● Modulus of elasticity, MPa (psi) ____________

☐ Reference data
● Calculation data

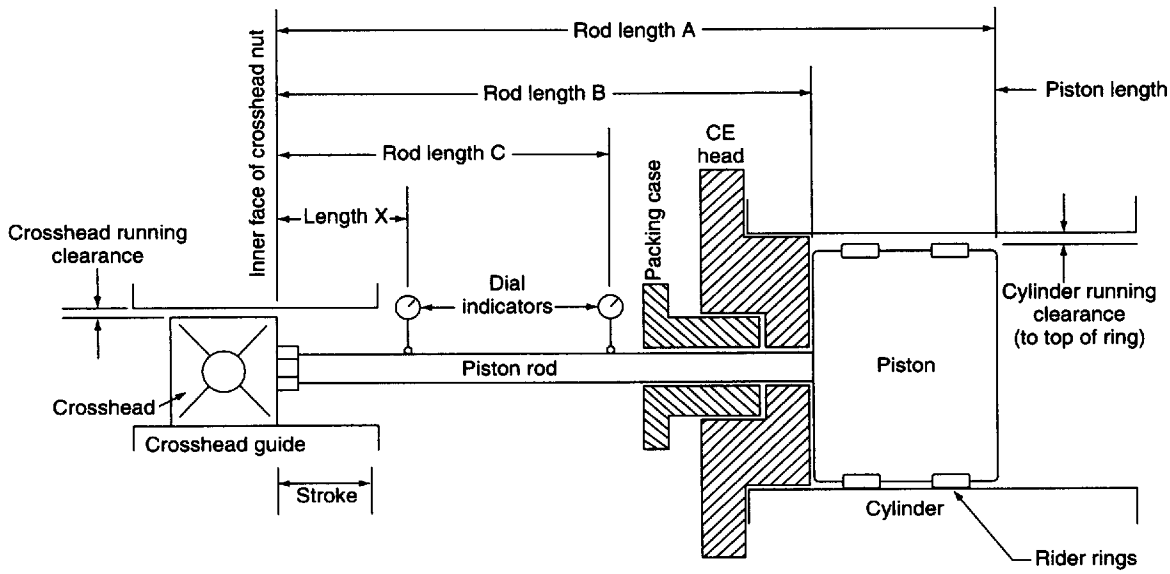
Note: The cylinder running clearance is the bore ID minus the OD across the rider rings. Use actual values for final calculations.

Figure C-5A—Data for Rod Runout Calculation

C-2, it can be seen that the longer the stroke, the greater the runout; and the shorter the piston rod, the greater the runout, for the same Δ *DROP*.

To see the effect of rider ring wear on vertical rod runout, use Figure C-9 as the initial reference and compare it to Figure C-8, which has a Δ *DROP* of 0.254 millimeter (0.010 inch). The 0.254 millimeter (0.010 inch) drop is representative of 0.254 millimeter (0.010 inch) rider ring wear, which changes the vertical rod runout by 0.0254 millimeter (0.001 inch) to 0.030 millimeter (0.0012 inch) from 0.056 millimeter (0.0022 inch).

Where there is much concern about rod runout, each application needs to be studied carefully in order to fully understand what the vertical rod runout should be under conditions of perfect alignment in order to make the right decision and proper adjustment.



☐ Throw number	*1*
☐ Stage	*1*
☐ Cylinder bore diameter	*20"*
● Cylinder running clearance	*0.080", 0.060", 0.040", 0.020", 0.010"*
● Crosshead running clearance	*0.020"*
● Stroke	*11"*
● Rod diameter	*3"*
● Rod length A	*110"*
● Rod length B	*95"*
● Rod length C Indicator Position	*80"*
● Rod length X Indicator Position	*14"*
☐ Rod material	*AISI 4140*
● Material density, kg/m³ (lb/in³)	*0.283 lb/in³*
● Modulus of elasticity, MPa (psi)	*30 x 10⁶ psi*

☐ Reference Data
● Calculation Data

Notes: The cylinder running clearance is the bore ID minus the OD across the rider rings. Use actual values for final calculations.

This example is based on US customary units.

Figure C-5B—Rod Runout Calculation Example

ROD RUNOUT

EXAMPLE OF COMPUTERIZED PRINTOUT USING THE CYLINDER DATA OF FIGURE C-5B

U.S. customary units

Piston rod runout calculation — By: Engineering — Ref: Runout sample
Customer: Runout
Size unit: 11" stroke

Piston rod runout calculation data

☐ Throw number	1	
☐ Stage	1	Ref: rod runout
☐ Cylinder bore diameter	20.00	At crosshead / At cylinder
• Cylinder running clearance	0.080	0.0061 / 0.0008
• Crosshead running clearance	0.020	Ref: piston Δ *DROP* = 0.030
• Stroke	11	
• Total rod length A	110	Enter rod lengths as integers only

		— Limits —	
Standard calculated rod runout per Figure C-2			
Vert rod runout - basis no sag	0.0030	0.0047	0.0014
Hor rod runout	0	0.0017	-0.0017

Rod sag calculation data

• rod diameter	3	☐ Rod material AISI 4140
• rod length B	95	
• material density lb/in^3	0.2830	
• modulus of elasticity E	3.00e+07	

Moment of inertia I	3.9761
Total rod weight	190.0

Maximum deflection piston end fixed per Figure C-3 — 0.007398 — Max at D = 0.4215 x length = 40.04" from free end (crosshead)
Ref: nominal runout due to sag = 0.0026

	Calculated Runout	—Runout Limits—	
Rod runout at cylinder	0.0008	0.0025	-0.0008
Rod runout at crosshead	0.0061	0.0077	0.0044
Horz runout	0	0.0017	-0.0017

ROD RUNOUT AT DIFFERENT CYLINDER CLEARANCES

Cylinder Running Clearance Inches	Crosshead Running Clearance Inches	Δ *DROP*	Rod Runout – Inches	
			At Crosshead	At Cylinder
0.080	0.020	0.030	0.0061	+0.0008
0.060	0.020	0.020	0.0051	-0.0002
0.040	0.020	0.010	0.0041	-0.0012
0.020	0.020	0.000	0.0031	-0.0022
0.010	0.020	-0.005	0.0026	-0.0027

—See Figures C-6 through C-10

Figure C-5C—Sample Printout for Rod Runout

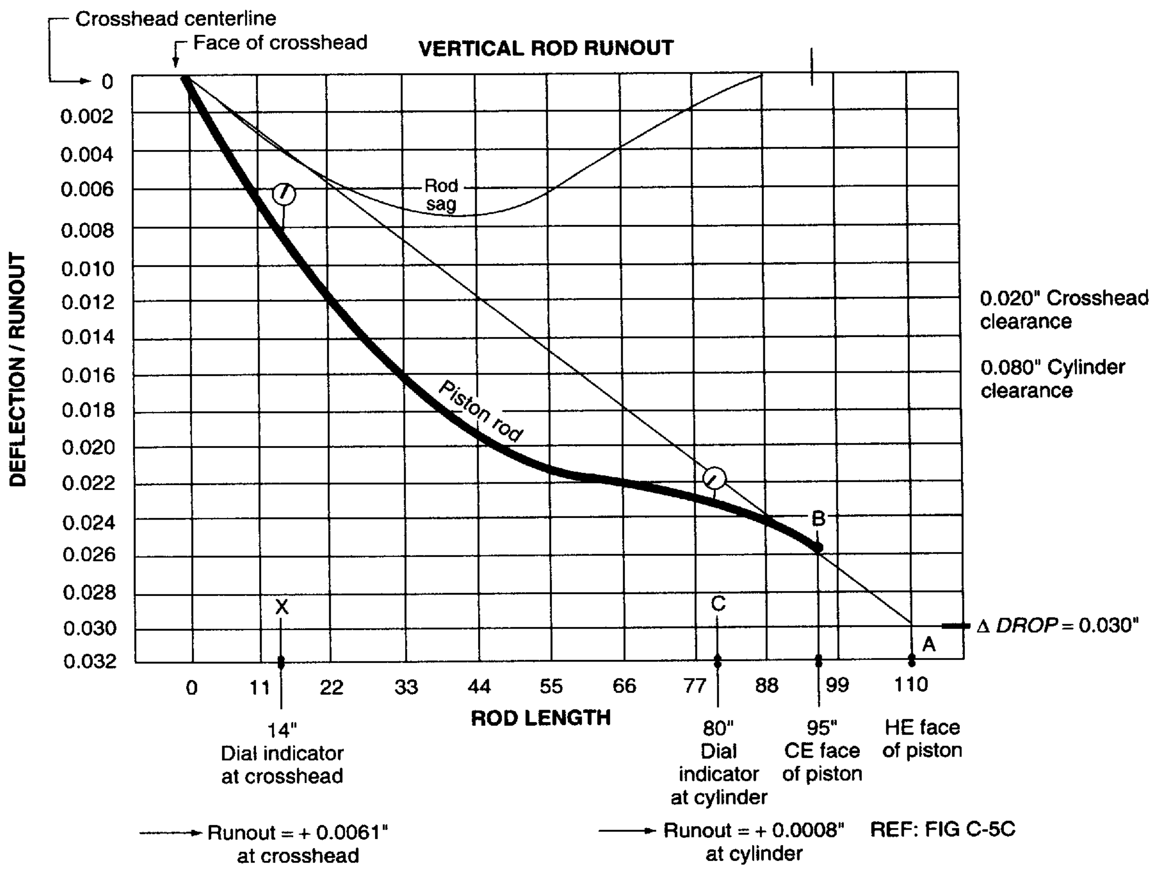


Figure C-6—Graphical Illustration of Rod Runout at 0.080 Inch Cylinder Running Clearance

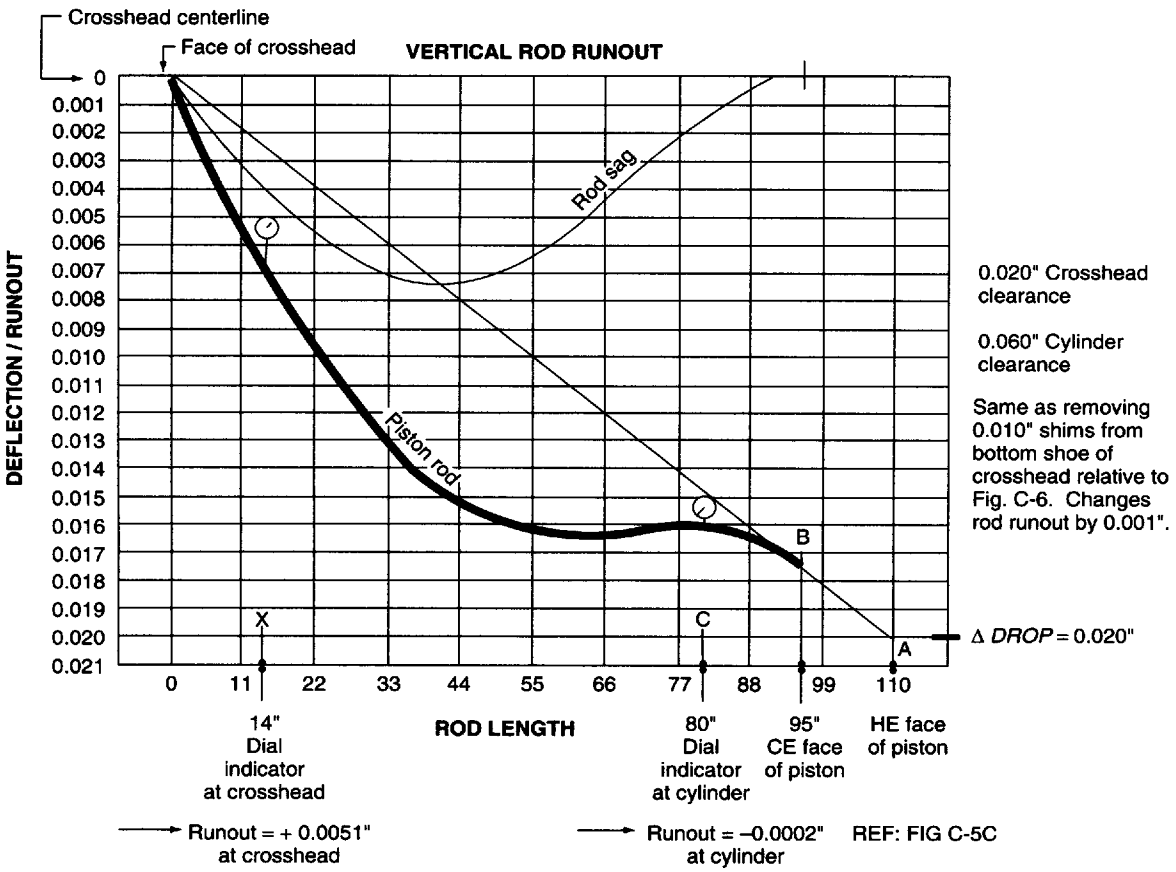


Figure C-7—Graphical Illustration of Rod Runout at 0.060 Inch Cylinder Running Clearance

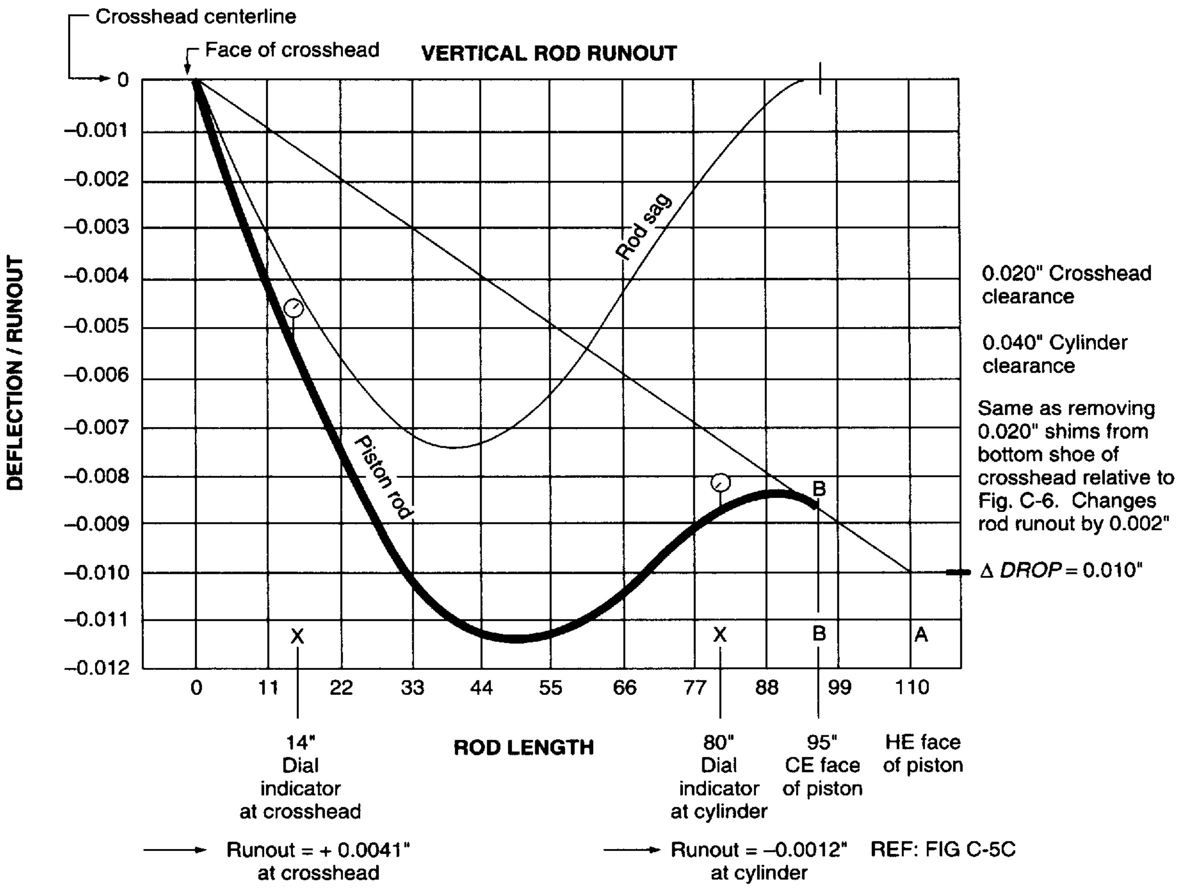


Figure C-8—Graphical Illustration of Rod Runout at 0.040 Inch Cylinder Running Clearance

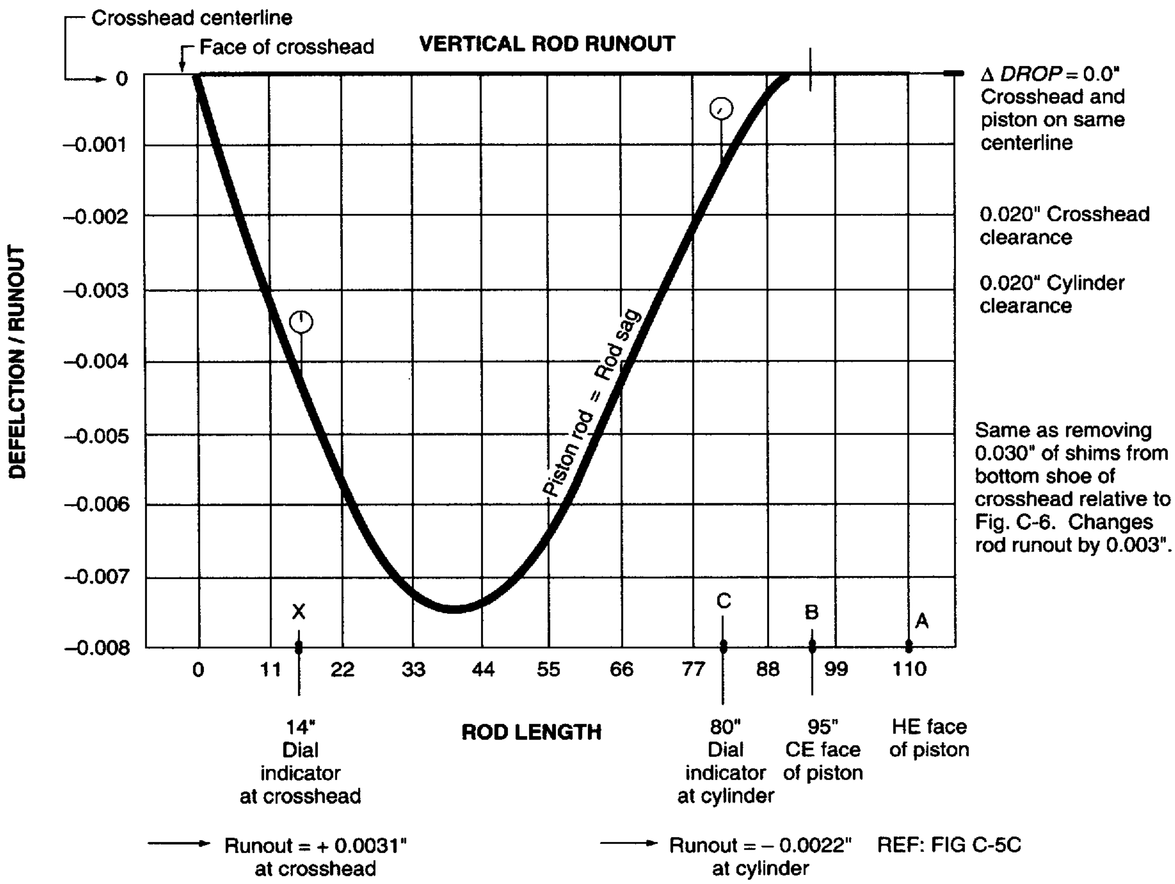


Figure C-9—Graphical Illustration of Rod Runout at 0.020 Inch Cylinder Running Clearance

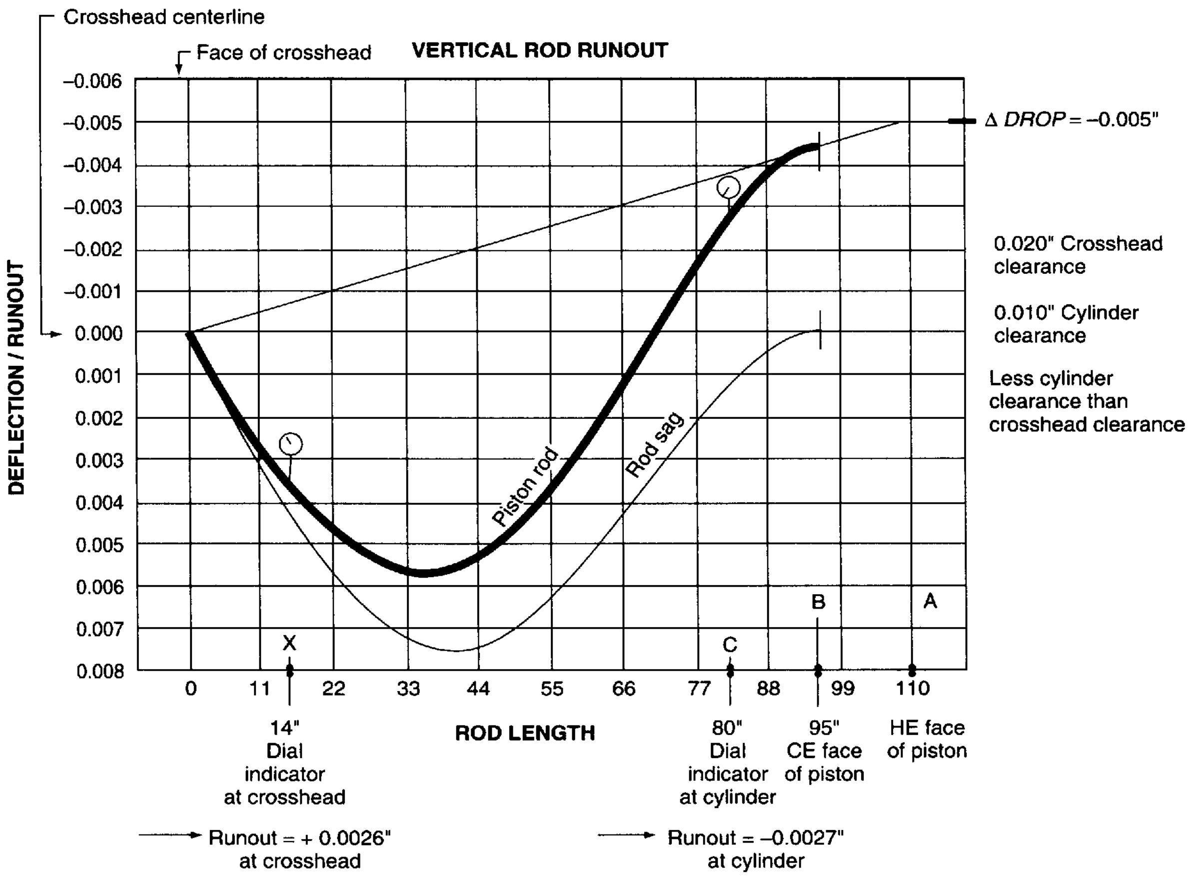


Figure C-10—Graphical Illustration of Rod Runout at 0.010 Inch Cylinder Running Clearance

APPENDIX D—REPAIRS TO GRAY OR NODULAR IRON CASTINGS

D.1 Scope

This appendix covers repair procedures that have been successfully applied to gray and nodular iron castings for compressor cylinders and related parts in various services. These procedures are only briefly described for the purpose of reference by the purchaser and the vendor; detailed descriptions of the procedures are beyond the scope of this standard. Limitations on the use of the procedures are included. These procedures should be applied only after careful evaluation of the situation by the purchaser and the vendor. When the service conditions of the casting involve toxic or hazardous gases, an even more exhaustive evaluation should be made.

D.2 Repair Methods and Limitations

In cylinders designed to handle gases having a molecular weight below 12, no repairs of any type shall be made to defects that leak between the cylinder bore and the water jacket during hydrostatic testing. With the purchaser's written approval, the repair methods specified in D.2.1 through D.2.3 may be used for compressor cylinders designed to compress gases with a molecular weight of 12 or greater.

D.2.1 Areas in which hydrostatic testing shows leaks between the water jacket and the atmosphere, or between the gas passage and the atmosphere, or between the water jacket and the gas passage may be repaired by plugging within the limits of ASTM A 395, or by approved procedures for vacuum-plus-pressure impregnating. Impregnating may be considered only for limited porosity leakage, and only after hydrostatic testing of both the water jacket and the gas passage has proved the mechanical integrity of the casting.

D.2.2 Defects that show up on machined surfaces, or in other areas where no leak is involved, may be repaired by iron plating. Such defects could include porosity in valve seats, or out-of-tolerance cylinder bores requiring a liner, or head and cylinder end faces. Plating repairs are excluded from critical areas such as seal bores, o-ring seating areas or surfaces swept by the compressor piston, where sharp edges could damage o-rings, piston rings, and so forth. See 2.14.6.2.

D.2.3 Damaged threaded holes in castings may be mechanically repaired by the use of shoulder studs or bushings.

D.3 Tests

After any part is repaired in accordance with D.2.1, D.2.2, or D.2.3, the part must be subjected to both a hydrostatic test at two times the maximum allowable working pressure and a helium test at the maximum allowable working pressure.

APPENDIX E—CONTROL LOGIC DIAGRAMMING

E.1 General

A system logic diagram is very useful during system design, checkout, and operation. Such a diagram is readily understood by electrical, instrument, and machinery engineers and by operations personnel. It becomes, in effect, the definitive specification from which the circuit designer works. The diagram is particularly helpful in prestart functional checkout of the system as well as in system troubleshooting. Once the diagram has been completed to describe the requirements of the equipment and process designers, the preparation of the instrument and electrical schematics becomes quite simple and positive.

Figure E-1 is a typical logic diagram indicating the control philosophy (power supply voltage levels, prestart interlock protection, alarm and shutdown features, loading and unloading, and the like) for a hypothetical reciprocating compressor. An explanation of the symbols will be found in Figure E-2. It is suggested that a similar diagram be prepared by the purchaser to accompany the data sheets submitted to the vendor in the inquiry.

Logic diagramming is used as a simple means of defining and analyzing system protection and safety. It is not necessary for the system analyst to know how a "not" gate or other logic function is built; it is only necessary to know the effect such a device has on a system in order to make it functional and safe. If the system requires an output signal to an alarm when there is no input signal (for example, when low pressure has allowed the frame lube oil pressure switch to open), the instrument and electrical system designers know how to provide this feature.

System logic diagrams are always drawn to show the devices as they will be at shutdown ambient conditions, that is, at ambient pressure and temperature, and zero flow and liquid level. This is the condition of the device on the manufacturer's shelf, thus simplifying the checking of the bills of material. Note that spaces are provided for device tag numbers and switch settings. Some of these values must be provided by the purchaser and others by the machine vendor. Beginning with the shutdown ambient conditions, the analyst must think through the startup procedures necessary to complete the switch-circuitry requirements for a ready-to-start condition, starting, lubricating, loading, and so forth. In the analysis, one must examine the effects of a decision on the process as well as on the equipment. For example, is it better to unload or shut down the compressor in case of low suction pressure (excessive rod load) or high suction knockout drum level?

The particular example presented in Figure E-1 is for a lubricated compressor fitted with fluorocarbon rings and packing. For a lubricated compressor with metallic rings or packing, the off-delay timer would be omitted after the low cylinder lube flow switch. For a nonlubricated compressor, the entire lubricator start-stop system and low flow switch would be eliminated.

The system can be expanded to include rod runout alarm and/or shutdown, additional knockout liquid level alarms, and so forth. It can show interlock to other process equipment. For example, upon loss of coolant flow in a recycle compressor cooling an exothermic process, it might be necessary to shut down process feed pumps and process heater fuel. All such interlocking should be shown on the logic diagram.

E.2 Example of Logic Analysis

The following paragraphs give an example of the logic analysis used in reviewing the system shown on Figure E-1.

The permissive start system is composed of protection from low frame lube oil pressure, high suction knockout liquid level, high discharge temperature, and low cylinder lube flow. All of these switches must be closed, and the motor protection devices must be satisfied in order to initiate a start.

The auxiliary frame oil pump will run in either the manual (hand) or the auto condition. When the minimum pressure is attained, the pressure switch in the auxilliary pump start system will open. To shut the auxilliary pump down, the reset button must be pushed. If the main pump is not supplying sufficient pressure, the pressure switch will still be closed and the auxiliary pump will restart as soon as the reset switch is released. This arrangement prevents the pump from cycling on and off once the minimum pressure is reached, and also makes it more difficult to leave the auxiliary pump in a disabled condition with the compressor running.

The lubricator system in this example has four logic restraint features, as follows:

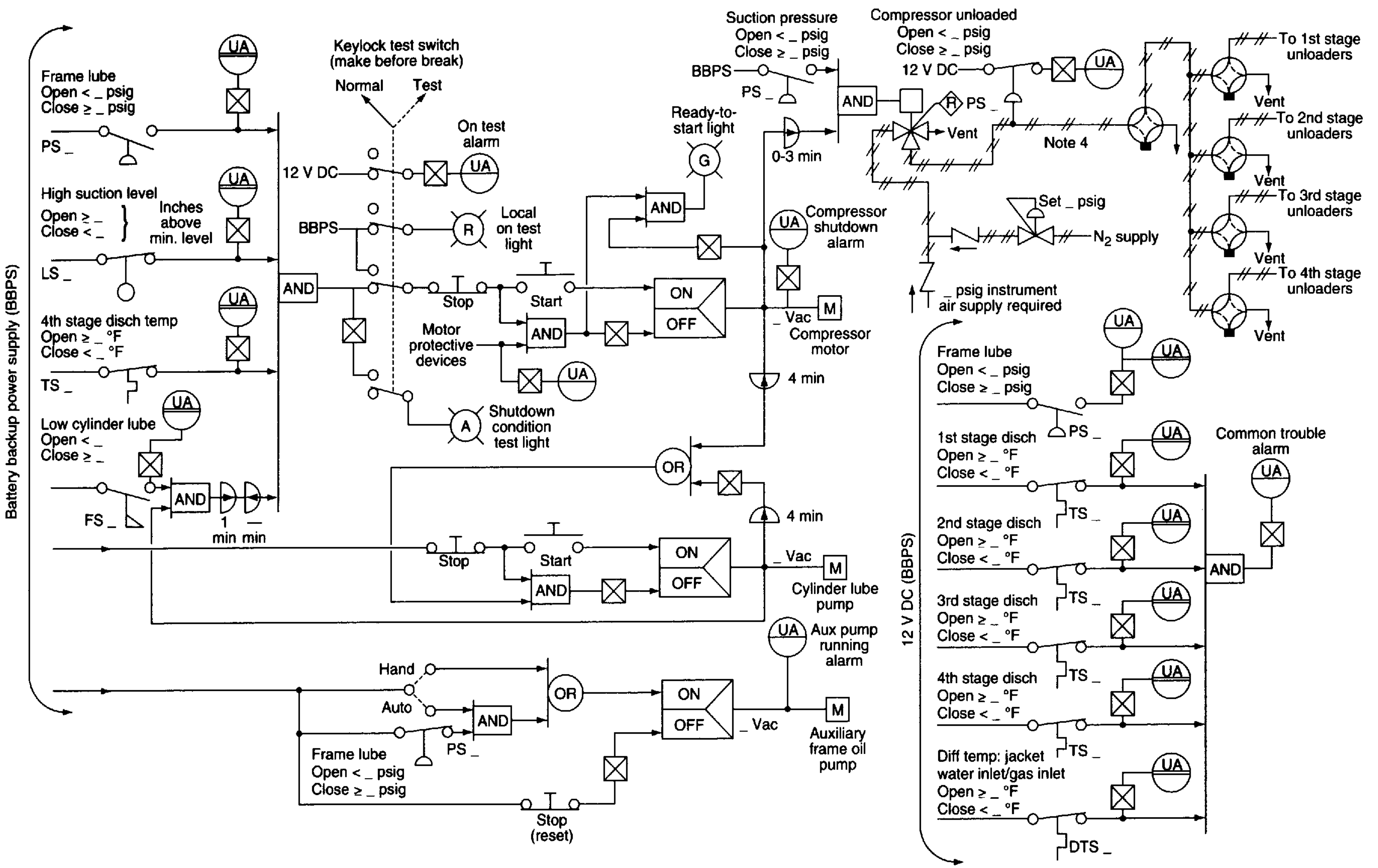
a. A 4-minute on-delay timer to shut down the lubricator if the compressor has not started, thus protecting the idle compressor from overlubrication at startup.
b. An on-delay timer to prevent the compressor from being started for 1 minute after the flow has been established, thus ensuring adequate prelube.
c. An off-delay timer to limit nonlubricated operation of this fluorocarbon-fitted compressor in the event of a loss of lubricator flow.
d. An off-delay timer to shut down the lubricator 4 minutes after the compressor is shut down, thus allowing a rapid restart within the 4-minute period but protecting against overlubrication as in Item a.

The lubricator is started by pushing the lubricator start button. One minute after lubricator flow is established, the permissive start system is completed and the ready-to-start light will come on, allowing the main motor to be started. If the compressor has not been started at the end of 4 minutes from the start of the lubricator, the 4-minute on-delay timer will time out and send a signal to the "not" gate. The "or" gate will no longer have an output signal to the "and" gate, which in turn no longer sends an input to the "not" gate, and the "not" gate sends an output shut-down signal to the lubricator motor starter. If the compressor has been started within the allotted 4 minutes, a signal is maintained through the "or" gate, and the lubricator keeps running.

The compressor is started by pushing the start button and the ready-to-start light will go out. The variable 0–3 minute on-delay timer prevents the compressor from being loaded until 100-percent speed is realized. At this time, if suction pressure is at or above minimum, the "and" gate will allow the solenoid valve to be latched supplying pressure to the cylinder loading system.

The compressor is shut down by the loss of any signal from the permissive start switches or the motor protective devices, or when the stop button is pushed. Upon shutdown, the cylinder loading supply pressure is removed through the solenoid valve. Unless the compressor is restarted within 4 minutes, the lubricator will shut down when the 4-minute off-delay timer has timed out.

All of the permissive switches can be functionally tested with the keylock test switch in the test position. A unit alarm will be annunciated so long as this switch is in the test position, and a local panel light will indicate a shutdown condition or an open switch.



Notes:
1. The vendor will fill in pressures, temperatures, and the like where blanks are provided for them.
2. All switches are shown in shelf condition, that is, at ambient pressure and temperature, and zero liquid level and flow.
3. See Figure E-2 for definitions of symbols.
4. Unloaders—pressure to load (reverse acting).

Figure E-1—Typical Logic Diagram for Fluorocarbon-Fitted Reciprocating Compressor (U.S. Customary Units)

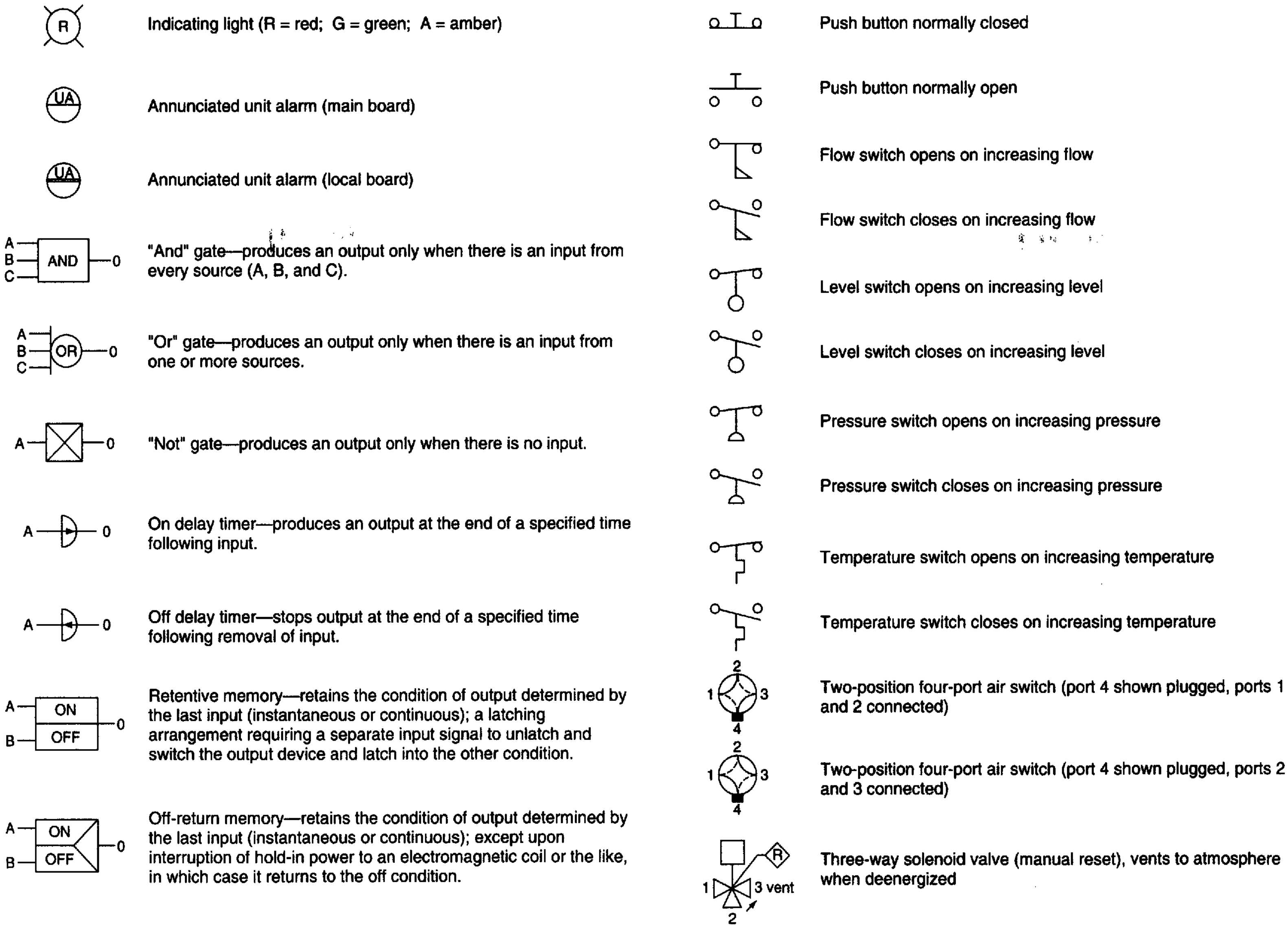


Figure E-2—Logic Diagram Symbols

APPENDIX F—VENDOR DRAWING AND DATA REQUIREMENTS

This appendix consists of a sample distribution record (schedule), followed by a representative description of the items that are presented numerically in the schedule. It is intended for purposes of organization and coordination and is not meant to be duplicated for use as is. Since different manufacturers will use different names for the same drawing, the items in the description column should be modified in the early stages of the order using the drawing names supplied by the manufacturer.

RECIPROCATING COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____________ ITEM NO. ____________
PURCHASE ORDER NO. ____________ DATE ____________
REQUISITION NO. ____________ DATE ____________
INQUIRY NO. ____________ DATE ____________
PAGE 1 OF 3 BY ____________
REVISION ____________
UNIT ____________
NO. REQUIRED ____________

FOR ____________
SITE ____________
SERVICE ____________

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[c] Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

DISTRIBUTION RECORD

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

Proposal	Review	Final	DESCRIPTION	Review—Due from vendor	Review—Received from vendor	Review—Returned to vendor	Final—Due from vendor	Final—Received from vendor
			1. Certified dimensional outline drawing (general arrangement) and list of connections.					
			2. Foundation plan showing anchor bolt locations.					
			3. Allowable flange loading (either cylinder or pulsation suppression device) and coordinates. See 2.6.2.2.					
			4. Driver outline.					
			5. Drive arrangement drawing.					
			6. Dimensional outline for all vendor-supplied major accessory equipment.					
			7. Performance data. See 5.3.3.1.					
			8. Packing box drawing(s).					
			9. Gas load, rod load, and crosshead load reversal and duration charts. See 5.3.3.2.					
			10. Starting speed versus torque curves. (For driver and compressor.)					
			11. Driver performance characteristics.					
			12. Tabulation of utility requirements.					
			13. List of unsafe or undesirable speeds. See 2.1.4.					
			14. Gear data.					
			15. Other driver data.					
			16. Shaft coupling assembly drawing and bill of materials.					
			17. Weld procedures. See 3.9.3.3.					
			18. Intercooler and aftercooler data.					
			19. Parts list with sectional drawings.					
			20. "Start-up" spares list. See 5.2.3, Item i.					
			21. Recommended normal maintenance spare parts. See 5.3.6.					
			22. Process schematic.					
			23. Frame and cylinder lube oil schematics and bill of materials.					
			24. Lube oil assembly drawings and list of connections.					
			25. Lube oil component drawings and data.					
			26. Coolant schematics and bill of materials.					
			27. Coolant assembly drawings and list of connections.					
			28. Coolant component drawings and data.					
			29. Distance piece vent, drain, and buffer schematics and list of connections.					
			30. Capacity control schematics and bill of materials.					

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

RECIPROCATING COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____ ITEM NO. ____
PURCHASE ORDER NO. ____ DATE ____
REQUISITION NO. ____ DATE ____
INQUIRY NO. ____ DATE ____
PAGE 2 OF 3 BY ____
REVISION ____
UNIT ____
NO. REQUIRED ____

FOR ____
SITE ____
SERVICE ____

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[c] Vendor shall furnish ____ copies and ____ transparencies of drawings and data indicated.
Vendor shall furnish ____ operating and maintenance manuals.

DISTRIBUTION RECORD

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

Proposal	Review	Final	DESCRIPTION	Review—Due from vendor	Review—Received from vendor	Review—Returned to vendor	Final—Due from vendor	Final—Received from vendor
			31. Instrumentation and electrical schematics and bill of materials.					
			32. Instrumentation and electrical arrangement drawing and list of connections.					
			33. Instrumentation and electrical wiring diagrams.					
			34. Instrumentation set-point list.					
			35. Instrumentation ISA data sheets.					
			36. Pulsation suppression device detail drawings and final ASME Code calculations.					
			37. Special tools list. See 3.11.1.					
			38. Fabrication, testing, and delivery schedule.					
			39. Drawing list.					
			40. Weather protection and climatization required.					
			41. Comments on purchaser's piping and foundation drawings. See 2.1.11 and 3.7.1.7.					
			42. Progress reports. See 5.3.5.					
			43. Torsional analysis report. See 2.5.1 and 3.1.2.6.					
			44. Data for an independant torsional analysis.					
			45. Lateral analysis report. See 2.5.1.					
			46. Acoustical and mechanical analysis report.					
			47. Data required for third-party acoustical and mechanical analysis.					
			48. Engineering analysis for fabricated cylinders. See 2.14.5.1.					
			49. Balancing data tabulation.					
			50. Valve dynamics report. See 2.7.9.					
			51. Data for an independent valve dynamic analysis.					
			52. Connection sketches. See 2.14.7.5.3.					
			53. Coupling alignment diagram.					
			54. As-built dimensions and data.					
			55. Hydrostatic test certificates. See 4.3.2.1.					
			56. Certified mechanical run test data (if test ordered).					
			57. Certified performance test data (if test ordered).					
			58. Non-destructive test procedures for fabricated cylinders.					
			59. Procedures for special or optional tests (if tests ordered).					
			60. Certified data from special or optional tests (if tests ordered). See 4.3.4.1.					
			61. Certified mill test reports.					

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

RECIPROCATING COMPRESSOR VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PAGE 3 OF 3 BY ______
DATE ______ REVISION ______

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[c] — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

DISTRIBUTION RECORD

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

Proposal	Review	Final	DESCRIPTION	Review—Due from vendor	Review—Received from vendor	Review—Returned to vendor	Final—Due from vendor	Final—Received from vendor
			62. Crankshaft ultrasonic test certificate. See 4.2.2.3.3.					
			63. Gas leak test certificates. See 4.3.2.2.					
			64. Valve leak test certificate.					
			65. As-built data sheets.					
			66. Installation manual. See 5.3.7.2.					
			67. Operation and maintenance manual. See 5.3.7.3.					
			68. Technical data manual. See 5.3.7.4.					
			69. Procedures for preservation, packaging, and shipping.					
			70. Shipping list.					
			71. Material Safety Data Sheets.					

[a]Proposal drawings and data do not have to be certified or as built. Typical data shall be clearly identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this 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.

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)

DESCRIPTION OF VDDR ITEMS

1. Certified dimensional outline drawings (general arrangement) and tables include, but are not limited to, the following:
   a. Size, type, rating, location, and identification of all customer connections, including vents, drains, lubricating oil, conduits, conduit boxes, electical and pneumatic junction boxes, and instruments. The vendor's plugged connections shall be identified. Details of special connections are required. See 2.6.4.3.
   b. The weight of (1) each assembly, (2) the heaviest piece of equipment which must be handled for erection, and (3) significant items to be handled for maintenance.
   c. All principal dimensions, including those required for piping design, maintenance clearances, and dismantling clearances. Valve maintenance clearance is also included if pulsation suppression devices are not supplied.
   d. Shaft centerline height.
   e. Shaft end separation.
   f. Center of gravity, vertical and plan location.
   g. Direction of rotation.
   h. When applicable, the make, size and type of couplings, and the location of guards and their coverage.
2. Foundation plan, including:
   a. Dimensions of mounting plates for the complete train and auxiliary systems, complete with diameter, number, and location of both holes and thickness of metal through which bolts must pass.
   b. Direction and magnitude of unbalanced forces and couples, and the location of the center of gravity.
   c. Jack screw location.
3. Allowable flange loading (either cylinder or pulsation suppression device) and coordinates. See 2.6.2.2. Allowable flange loading(s) for all cylinder (or pulsation bottle) connections, including anticipated thermal movements referenced to a defined point, and X, Y, Z coordinate system.
4. Driver outline. Certified dimensional outline drawing for the driver and all its auxiliary equipment, including:
   a. Size, location, orientation, and purpose of all customer connections, including conduit boxes, conduit, instrumentation, and any piping or ducting.
   b. ANSI rating and facing for any flanged connections.
   c. Size and location of anchor bolt holes, jack bolts, and thickness of sections through which bolts must pass.
   d. Total weight of each item of equipment (motor and auxiliary equipment) plus loading diagrams, heaviest weight, and name of the part.
   e. Overall dimensions and all horizontal and vertical clearances necessary for dismantling, and the approximate location of lifting lugs.
   f. Shaft centerline height.
   g. Shaft and dimensions, plus tolerances for the coupling.
   h. Direction of rotation.
5. Drive arrangement drawing, including, but not limited to, the following:
   a. Flywheel data.
   b. Motor weight.
   c. Rotating inertia.
   d. Stator shift.
   e. Air gap.
6. Dimensional outline for all vendor-supplied major accessory equipment.
7. Performance data. See 5.3.3.1.
8. Packing box drawing (one for each packing box type).
9. Gas load, rod load, and crosshead load reversal and duration charts. See 5.3.3.2.
10. Starting speed versus torque curves. (For driver and compressor - on the same chart.) Acceleration time.
11. Driver performance characteristics and performance data, including:
   a. For induction motors 200 horsepower and smaller:
      1. Efficiency and power factor at one-half, three-quarter, and full load.
      2. Speed-torque curves.
   b. For induction motors 250 horsepower and larger, certified test reports for all tests run and performance curves as follows:
      1. Time-current heating curve.
      2. Speed-torque curves at 70, 80, 90, and 100 percent of rated voltage.
      3. Efficiency and power factor curves from 0 to rated service factor.
      4. Current versus load curves from 0 to rated service factor.
      5. Current versus speed curves from 0 to 100 percent of rated speed.
      6. Permissible safe stall time - hot and cold.
   c. For synchronous motors:
      1. Speed-torque, speed-current, and speed-power factor curves at 70, 80, 90, and 100 percent of rated voltage.
      2. Pull-in and pull-out torque.
      3. Permissible safe stall time - hot and cold.
      4. Efficiency and power factor curves from 0 to rated service factor.
      5. Speed-current pulsation curve during normal acceleration.
12. Tabulation of utility requirements (may be on data sheets).
13. List of unsafe or undesirable speeds. See 2.1.4.
14. Gear data.
   a. Certified dimensional outline drawings and list of connections, including:
      1. The size, rating, location, and identification of all customer connections, including vents, drains, lube oil, conduits, conduit boxes, junction boxes, and instruments.

2. All principal dimensions, including those required for the purchaser's foundation, piping design, maintenance clearances, and dismantling clearances.
3. Overall and handling weights.
4. Shaft centerline heights.
5. Shaft and dimensions and tolerances for the couplings.
6. Direction of rotation.
7. Location of the center of gravity of the gear unit.
8. The size and location of anchor bolt holes and thickness of sections through which bolts must pass.
9. Thermal and mechanical movements of casings and shafts.

b. Cross-sectional drawing and bill of materials, including axial gear and pinion float.
c. As-built data sheets, including:
1. Data for torsional analysis.
2. Lateral critical speed reports when specified.

d. Certified mechanical running test data.
e. Certified gear manufacturer's standard test data including gear contact test data.
f. Optional test data and reports mutually agreed upon by the purchaser and the gear manufacturer.
g. Spare parts recommendations.

15. Other driver data, including:
a. Cross-sectional drawing and bill of materials, including the axial rotor float.
b. As-built data sheets.
c. Certified drawings of driver auxiliary systems, including wiring diagrams for each auxiliary system supplied. The drawings shall clearly indicate the extent of the system to be supplied by the manufacturer and the extent to be supplied by others.
d. Spare parts recommendations.
e. Other driver data per driver VDDR.

16. Shaft coupling assembly drawing and bill of materials, including:
a. Allowable misalignment tolerances.
b. Hydraulic mounting procedure.
c. Shaft end gap and tolerance.
d. Coupling guards.

17. Weld procedures for fabrication and/or repair, including those in 3.9.3.3.
18. Intercooler and aftercooler data, including, but not limited to:
a. Dimensional outline drawings.
b. TEMA data sheets.
c. Final ASME code calculations.

19. Parts list with sectional drawings. The parts list shall include pattern number, stock or production drawing numbers, and the materials of construction. The list shall completely identify each part so that the purchaser may determine interchangeability of parts with other equipment furnished by the same manufacturer. Standard purchased items shall be identified by the original manufacturer's name. Materials shall be identified as specified in 2.14.1.2
20. "Start-up" spares list. See 5.2.3, Item i.
21. Recommended normal maintenance spare parts. See 5.3.6.
22. Process schematic, a schematic diagram of the process fluids flowing through the machine, including:
a. Steady state and transient gas flow rates, temperatures, and pressures.
b. Cooler heat loads.
c. Pipe, tubing, and valve sizes of equipment provided by the vendor.
d. Instrumentation, safety devices, and control schemes.
e. Bill of materials.

23. Frame and cylinder lube oil schematics, including the following:
a. Steady-state and transient oil flows and pressures at each point.
b. Control, alarm, and trip settings (pressure and recommended temperatures).
c. Total heat loads.
d. Utility requirements, including electrical, water, and air.
e. Pipe, tubing, and valve sizes.
f. Instrumentation, safety devices, and control schemes.
g. Bills of materials.

24. Lube oil assembly drawings and list of connections. Lube oil system assembly and arrangement drawing(s), including size, rating location of all customer connections.
25. Lube oil component drawings and data, including:
a. Outline and sectional drawings and data sheets for auxiliary pumps and drivers.
b. Outline and sectional drawings and data sheets for coolers, filters, and reservoir.
c. Instrumentation.
d. Spare parts lists and recommendations.

26. Coolant schematics and bill of materials. Cooling (including packing cooling) or heating schematic and bill of materials, including cooling or heating media, fluid flows, pressure, pipe, and valve sizes, instrumentation, and orifice sizes.
27. Coolant assembly drawings and list of connections. Coolant (including packing cooling) or heating system assembly and arrangement drawing(s), including size, rating location of all customer connections.
28. Coolant component drawings and data.
a. Outline and sectional drawings and data sheets for pumps and drivers.
b. Outline and sectional drawings and data sheets for coolers, filters, and reservoir.
c. Instrumentation.
d. Spare parts lists and recommendations.

29. Distance piece vent, drain, and buffer schematics and list of connections. Distance piece vent, drain, and purge schematic and bill of materials, including media, fluid flows,

pressure, pipe, tube, and valve sizes and instrumentation.
30. Capacity control schematics and bill of materials.
31. Instrumentation and electrical schematics and bill of materials for all systems, including pneumatic and hydraulic systems (including bar over device limit switch).
32. Instrumentation and electrical arrangement drawing and list of connections (including pneumatic and hydraulic systems), including but not limited to:
a. Control panel general arrangement.
b. Control panel certified outline.
c. Control panel bill of materials.
33. Instrumentation and electrical wiring diagrams for all systems.
34. Instrumentation set-point list, including:
a. Vibration alarm and shutdown limits.
b. Bearing temperature alarm and shutdown limits.
c. Lube oil temperature alarm and shutdown limits.
d. Lube oil pressure alarm and shutdown limits.
e. Gas discharge temperature alarm and shutdown limits.
f. Frame oil level alarm limit.
g. Rod packing temperature alarm.
h. Oil filter differential pressure alarm.
i. Inlet separator level shutdown.
j. Cylinder lubrication protection.
k. Jacket water protection.
35. Instrumentation ISA data sheets.
36. Pulsation suppression device detail drawings and final ASME Code calculations.
37. Special tools list. See 3.11.1. List of special tools furnished for maintenance.
38. Fabrication, testing, and delivery schedule. See Item 42. Milestone fabrication, testing, and delivery schedule, including vendor buyouts.
39. Drawing list, including latest revision numbers and dates.
40. Weather protection and climatization required.
41. Comments on purchaser's piping and foundation drawings. See 2.1.11 and 3.7.1.7.
42. Progress reports. See 5.3.5. See Item 38. Including:
a. Planned and actual milestone dates.
b. Engineering and manufacturing information on all major components.
c. Details of cause(s) of delays.
43. Torsional analysis report (see 2.5.1. and 3.1.2.6), including, but not limited to, the following:
a. Complete description of method used.
b. Graphic display of mass elastic system.
c. Tabulation identifying the mass moment and torsional stiffness for each component identified in the mass elastic system.
d. Graphic display of exciting forces versus speed and frequency.
e. Graphic display of torsional critical speeds and deflections (mode shape diagram).
f. Effects of proposed changes on analysis.
g. Current pulsation analysis.
44. Data for an independent torsional analysis.
45. Lateral analysis report (see 2.5.1), including, but not limited to, the following:
a. Method used (complete description).
b. Graphic display of critical speeds vs. operating speeds.
c. Graphic display of bearing and support stiffness and its effect on critical speeds.
d. Journal static loads.
e. Stiffness and damping coefficients.
46. Acoustical and mechanical analysis report (see 3.9 and Appendix M), including, but not limited to:
a. Design approach (see 3.9.2) and method used (complete description), including description of design techniques used.
b. Findings and comparison with allowables.
c. Effects of required modifications and marked-up drawings showing changes.
d. Other information as required by Appendix M.
47. Data required for third-party acoustical and mechanical analysis. Information described in Appendix N, Section 4.

Note: It is the purchaser's responsibility to provide some of the information described.

48. Engineering analysis for fabricated cylinders. See 2.14.5.1.
49. Balancing data tabulation. Listing of weight balance data for each throw, including piston, rod, crosshead, nuts, bushings, bearings and balance weights; also includes both design target weights and actual assembly weights. The allowable weight tolerance per throw shall be stated.
50. Valve dynamics report. See 2.7.9.
51. Data for an independent valve dynamic analysis.
52. Connection sketches. See 2.14.7.5.3.
53. Coupling alignment diagram. Shaft alignment diagrams (vertical and horizontal), including recommended coupling limits during operation. Note all shaft-end position changes and support growths from 15°C (60°F) ambient reference temperature or other reference temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.
54. As-built dimensions and data, including:
a. Fits, clearances, and runouts measured during final assembly.
b. Nameplate data for each cylinder.
c. Cylinder minimum and design clearances for each end of each cylinder.
d. Volume of all clearance pockets, plugs, or bottles installed on each cylinder.
e. Crank angle phasing.
55. Hydrostatic test certificates. See 4.3.2.1.
56. Certified mechanical run test data (if test ordered).
57. Certified performance test data (if test ordered).
58. Non-destructive test procedures for fabricated cylinders.

59. Procedures for any special or optional tests (if tests ordered).
60. Certified data from special or optional tests (if tests ordered). See 4.3.4.1.
61. Certified mill test reports of items as agreed in the precommitment or pre-inspection meeting(s). Physical and chemical data.
62. Crankshaft ultrasonic test certificate. See 4.2.2.3.3.
63. Gas leak test certificates. See 4.3.2.2.
64. Valve leak test certificate.
65. As-built data sheets for compressor, gear, driver, and auxiliary equipment, including gas data. See 2.1.15.
66. Installation manual (see 5.3.7.2) describing the installation requirements for the complete train, including the drawings necessary for assembly of the equipment and location of field connections, and including, but not limited to, the following:
  a. Section 1 - Compressor.
    1. Items 1, 2, 3, 40, 53.
    2. Grouting. (See 3.5.1.2.15.)
    3. Setting equipment, rigging procedures, component weights, and lifting diagram.
    4. Dismantling clearances.
    5. Motor air gap data. (See 3.1.2.11.)
    6. Preservation and storage requirements. (See 4.4.2.)
    7. Field assembly procedures, including frame and cylinder alignment requirements.
  b. Section 2 - Driver.
    1. Storage and preservation.
    2. Setting gear, rigging procedures, component weights, and lifting diagram.
    3. Piping recommendations.
    4. Composite outline drawing for driver including anchor bolt hole locations.
    5. Dismantling clearances.
    6. Thermal and mechanical movements of frame and shaft.
  c. Section 3 - Gear.
    1. Storage and preservation.
    2. Setting gear, rigging procedures, component weights, and lifting diagram.
    3. Piping recommendations.
    4. Composite outline drawing for gear including anchor bolt hole locations.
    5. Dismantling clearances.
    6. Thermal and mechanical movements of casing and shaft.
  d. Section 4 - Auxiliary Equipment.
    1. Storage and preservation.
    2. Setting equipment, rigging procedures, component weights, and lifting diagram.
    3. Piping recommendations.
67. Operation and maintenance manual (see 5.3.7.3) describing the operating and maintenance procedures, requirements, and limitations for the complete train and auxiliary equipment, including, but not limited to, the following:
  a. Section 1 - Operation.
    1. Initial commissioning and start-up, including final test and checks.
    2. Normal start-up.
    3. Normal shutdown.
    4. Emergency shutdown.
    5. Operating limits, including item 27 above.
    6. Lube oil recommendations, including injection rates, and specifications.
    7. Routine operational procedures.
    8. Items 22, 30, and 34.
  b. Section 2 - Maintenance, Disassembly, Repair, and Reassembly. Instructions for the complete train and auxiliary and accessory equipment including, but not limited to, the following:
    1. Valve overhaul data.
    2. Cylinder overhaul data.
    3. Table of bolt torques. The required torque values or elongations for tensioning, the valve cover, valve hold down bolts, crank and main bearing bolts, piston and crosshead nuts, flange bolts, and any other bolts that the vendor feels are critical. Data should be included for fasteners in both the lubricated and non-lubricated condition.
    4. Fits and clearances for wearing parts - recommended, maximum, and minimum.
    5. Items 4, 8, 19, 21, 37, 49, 53, 54, and 65.
    6. Routine maintenance requirements.
    7. Maximum allowable crankshaft web deflection.
  c. Section 3 - Performance Data. Items 7, 9, and 10.
  d. Section 4 - As-Built Data. Items 54 and 65.
  e. Section 5 - Drawings and Data.
    1. Drawings in the manual shall be for the specific equipment supplied. Typical drawings are unacceptable.
    2. Items 1, 5, 6, 8, 11, 15, 16, 19, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 36, and 39.
68. Technical data manual. See 5.3.7.4.
  a. Technical and quality control data for technical support personnel, for the complete train and auxiliary equipment.
  b. Items include, but are not limited to: 1–16, 18–20, 23, 26, 29–31, 33–37, 39–40, 43, 45–50, and 53–65.
69. Procedures for preservation, packaging, and shipping.
70. Shipping list, including all major components that will ship separately.
71. Material Safety Data Sheets.

APPENDIX G—FIGURES AND SCHEMATICS

G.1 General

The schematics presented here illustrate the general philosophy and requirements of this standard, and are typical of commonly used systems; they are not intended to include all details, such as vent and drain details and minor piping connections to permit assembly. The systems may be modified as necessary with the mutual agreement of the purchaser and vendor.

Instrument piping and valving details are not shown on typical schematics. Such requirements, including on-line testing requirements, shall be mutually agreed upon by the purchaser and vendor.

Requirements for all of the systems illustrated here are covered in the main text, as indicated by the cross references in the notes accompanying each figure. Further elaboration on the details of pressure packing to minimize process gas emissions is given in G.2.

G.2 Minimizing Process Gas Leakage

Refer to Appendix I for distance piece vent, drain, and inert gas buffer systems for minimizing process gas leakage.

G.3 Legend for Schematics

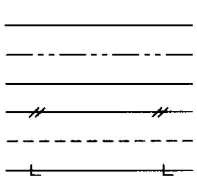
The abbreviations and symbols used in the schematics in this appendix are defined below.

G.3.1 FLOW DIAGRAM IDENTIFICATION LETTERS

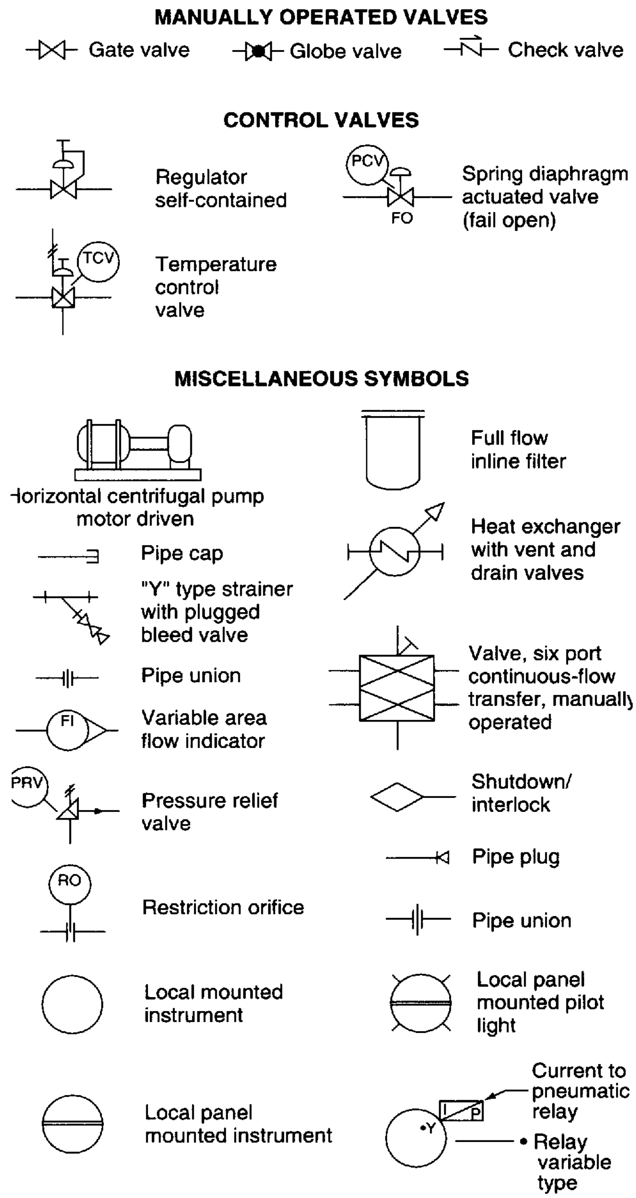
Letter	First Letter	Subsequent Letters
A	Analysis	Alarm
C	Conductivity (Electrical)	Controller
D	Density (Sp. Gr.)	Differential
E	Voltage (EMF/Electrical)	Element (Primary)
F	Flow	Ratio (Fraction)
G	Gauging (Dimensional)	Glass/Gauge
H	Hand Actuated (Manual)	High
I	Current (Amps)	Indicator
L	Level	Light/Low
O	(Unclassified)	Orifice (Restriction)
P	Pressure/Vacuum	Point
S	Speed/Frequency	Safety/Switch
T	Temperature	Transmitter
V	Vibration/Viscosity	Valve
Y	(Unclassified)	Relay

G.3.2 SYMBOLS

LINE AND PIPING SYMBOLS IDENTIFICATION

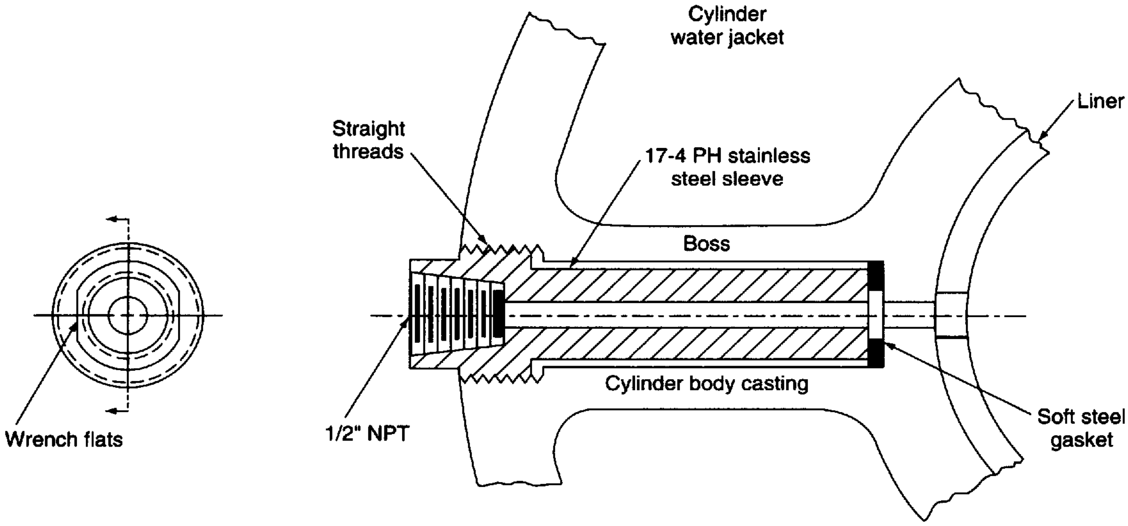


Piping line by vendor
Piping by contractor or user
Process instrument line
Instrument pneumatic line
Electrical signal
Hydraulic signal



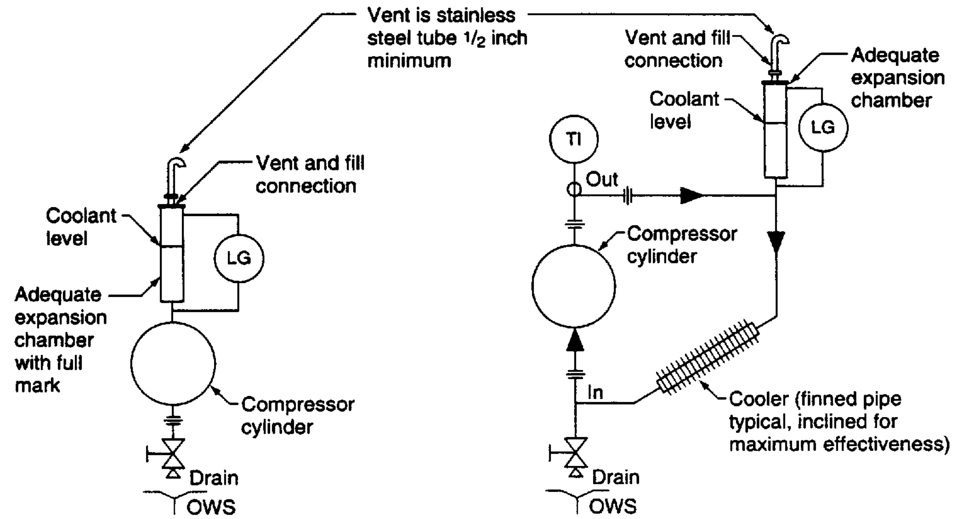
ABBREVIATIONS

CSO – Car Seal Open
FO – Fail Open
NO – Normally Open
OWS – Oily Water Sewer
FC – Fail Closed
NC – Normally Closed



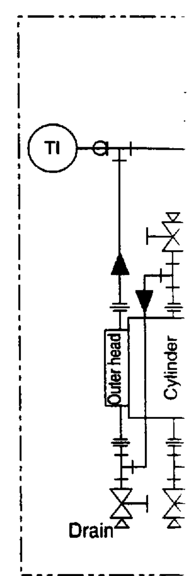
Notes:
1. See 2.6.4.6.
2. This typical arrangement utilizes a 17-4 stainless steel sleeve as a standard compressor cylinder design. The sleeve is installed during manufacture of the cylinder, providing a high-strength, corrosion resistant passage through a minor boss area. The design installation arrangement of the 17-4 stainless steel sleeve may vary among manufacturers.

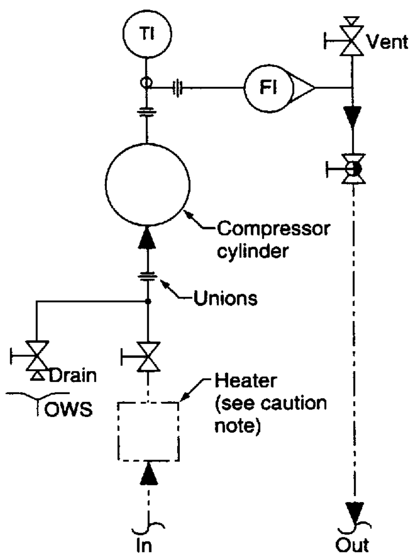
Figure G-2—Typical Cylinder Indicator Tap Connection



PLAN A
STATIC (STANDPIPE) SYSTEM

PLAN B
THERMOSYPHON SYSTEM





PLAN C
FORCED COOLING SYSTEM

Notes:
1. Instrumentation shown is minimum required. The purchaser may wish to specify additional devices.
2. Flow through cylinders may be either series or parallel.
3. See 2.6.3 and 3.7.4.
4. Heaters used to preheat the cylinder cooling water (if needed to meet the requirements of 2.6.3.3 or 2.6.3.5) may be electric, hot water, or steam. They must be sized to take into account heat losses of surface areas of the cylinder, pipe, and fittings. Good judgment must be exercised so that heaters will not be undersized.
5. Normal level is above the highest point of the cylinder piping.
6. Cooler to have vents and drains on both shell and tube side.
7. The system shown is typical: more or less equipment may be furnished.
8. Series flow.
9. Parallel flow.

CAUTION: When jacket water temperature is to be controlled by steam sparging, the following precautions should be observed:
a. A silent (water-hammer-cushion type) steam sparger should be placed in the water inlet line to the jacket system.
b. The water flow rate must remain constant in accordance with the manufacturer's requirements.
c. The steam flow into the water should be regulated automatically to maintain the water jacket temperatures in accordance with 2.6.3.3.

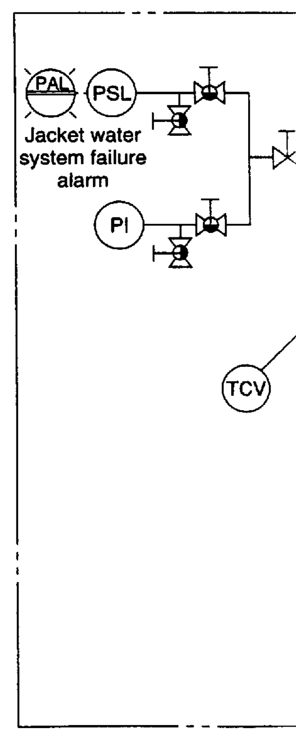
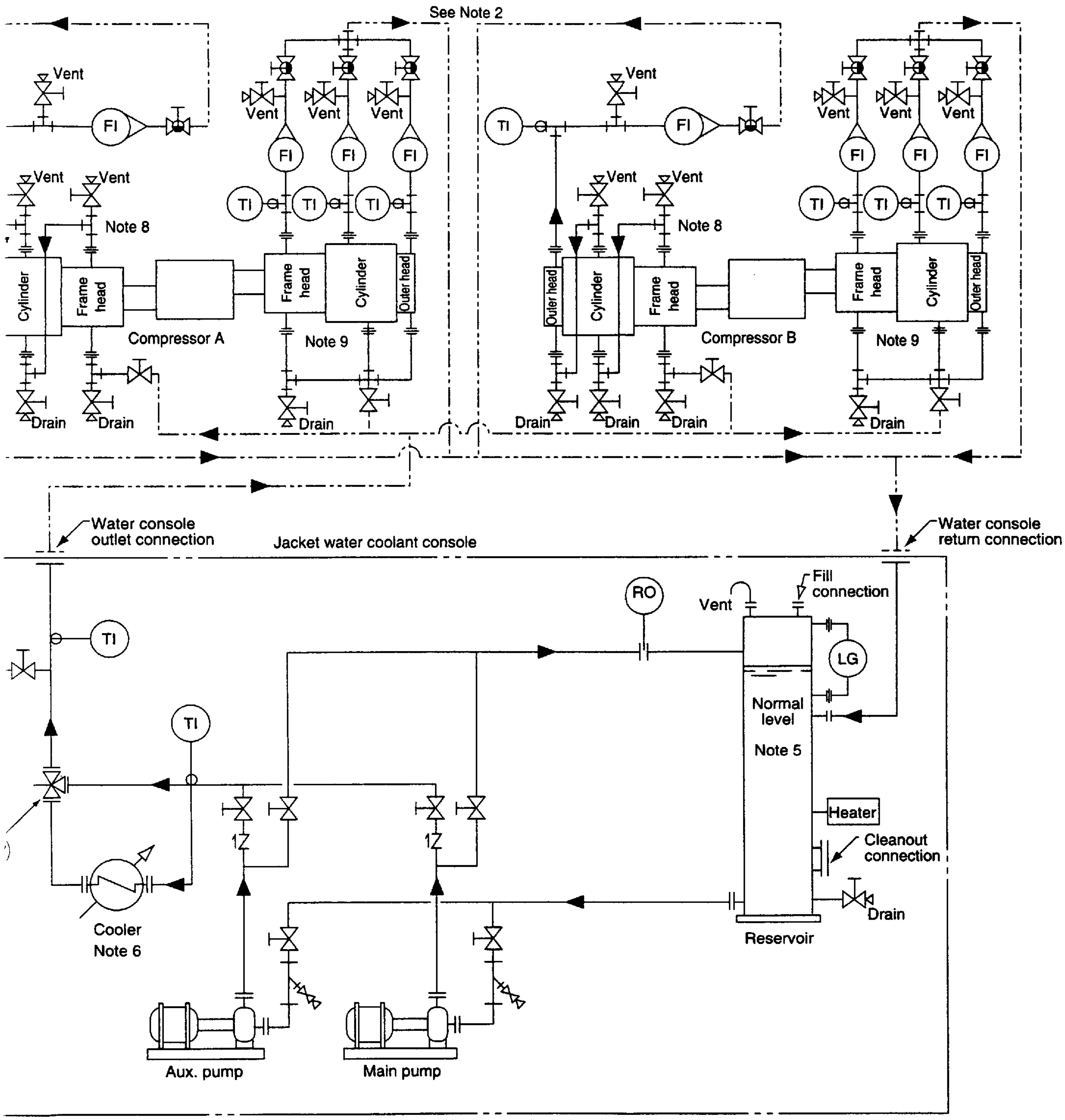
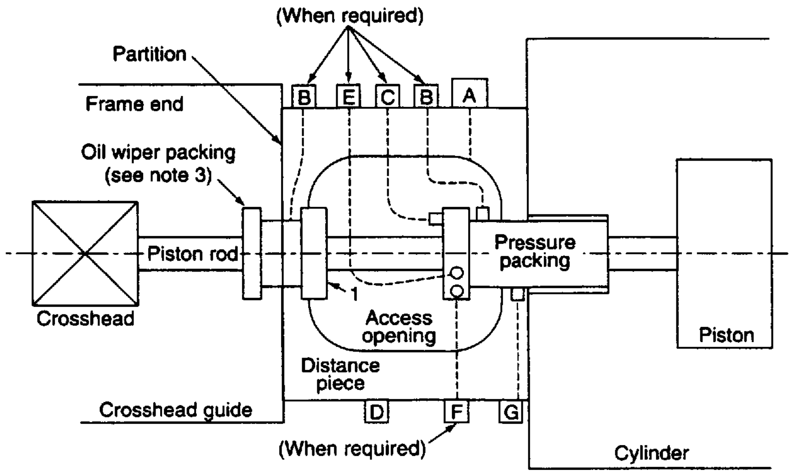


Figure G-1—



PLAN D
JACKET WATER COOLING SYSTEM

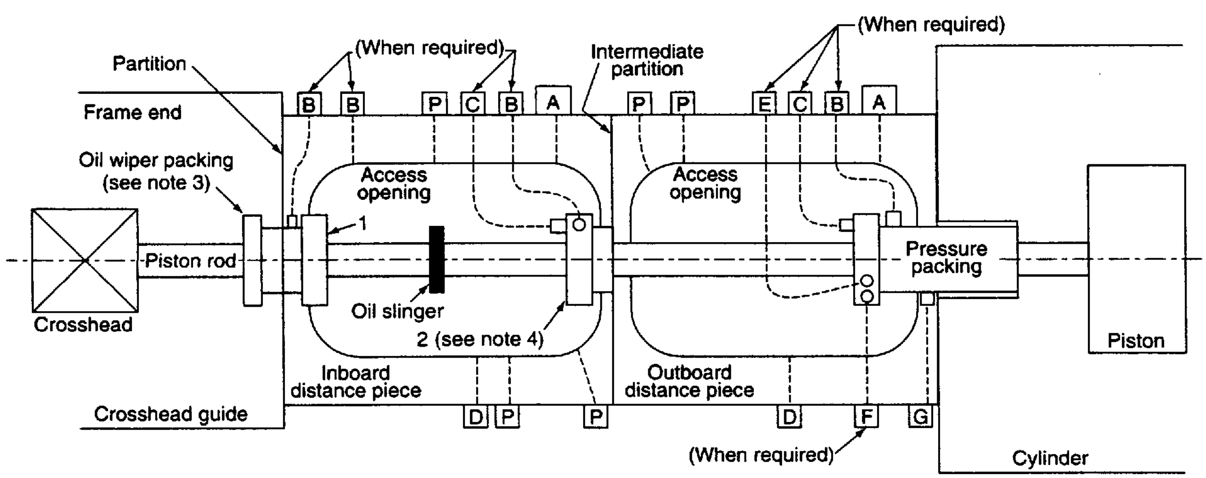
1—Cylinder Cooling Systems



Legend:
1. Seal or buffer packing, distance
2. Intermediate seal or buffer packi
access covers required)

Connections (see 2.10.5 for sizes):
A Vent, distance piece
B Purge, buffer, or pressure, packir
C Lube, pressure packing
D Drain, distance piece
E Coolant out, pressure packing
F Coolant in, pressure packing
G Common vent and drain, pressu
P Plugged connection

TYPE A
SHORT SINGLE-COMPARTMENT DISTANCE PIECE
(MAY BE INTEGRAL WITH CROSSHEAD GUIDE OR CRANK END HEAD)



TYPE C
LONG TWO-COMPARTMENT OR DOUBLE DISTANCE PIECE ARRANGEMENT
(INBOARD AND OUTBOARD DISTANCE PIECES EACH OF SUFFICIENT
LENGTH FOR OIL SLINGER TRAVEL)

Notes:
1. See 2.10 and 2.11.3.
2. The orientation of distance-piece and packing-flange/case connections may vary depending on the individual distance piece and the type of packing case used.

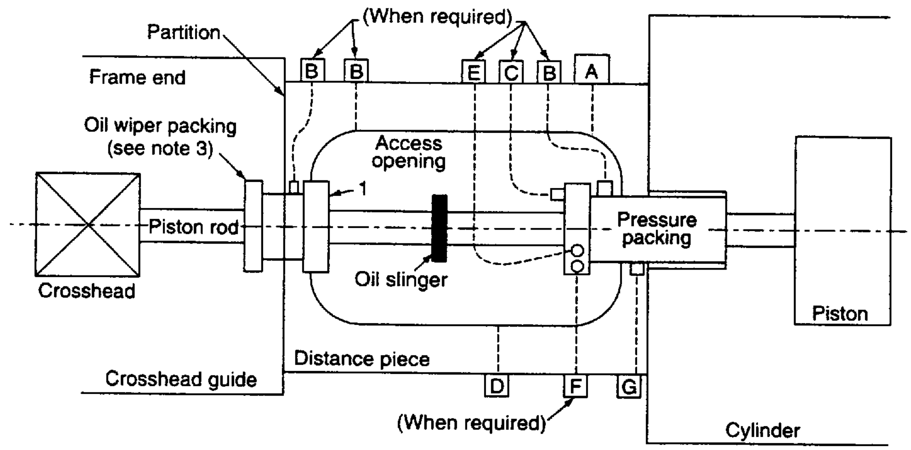
Figure G-3—Distance Piece a

:e piece
:king, distance piece (solid

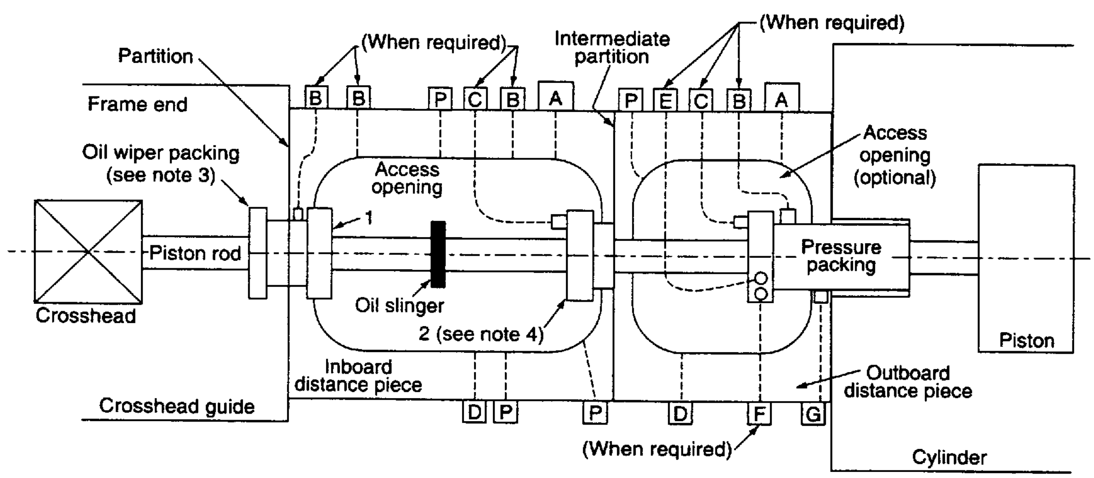
;):

:king or distance piece

sure packing



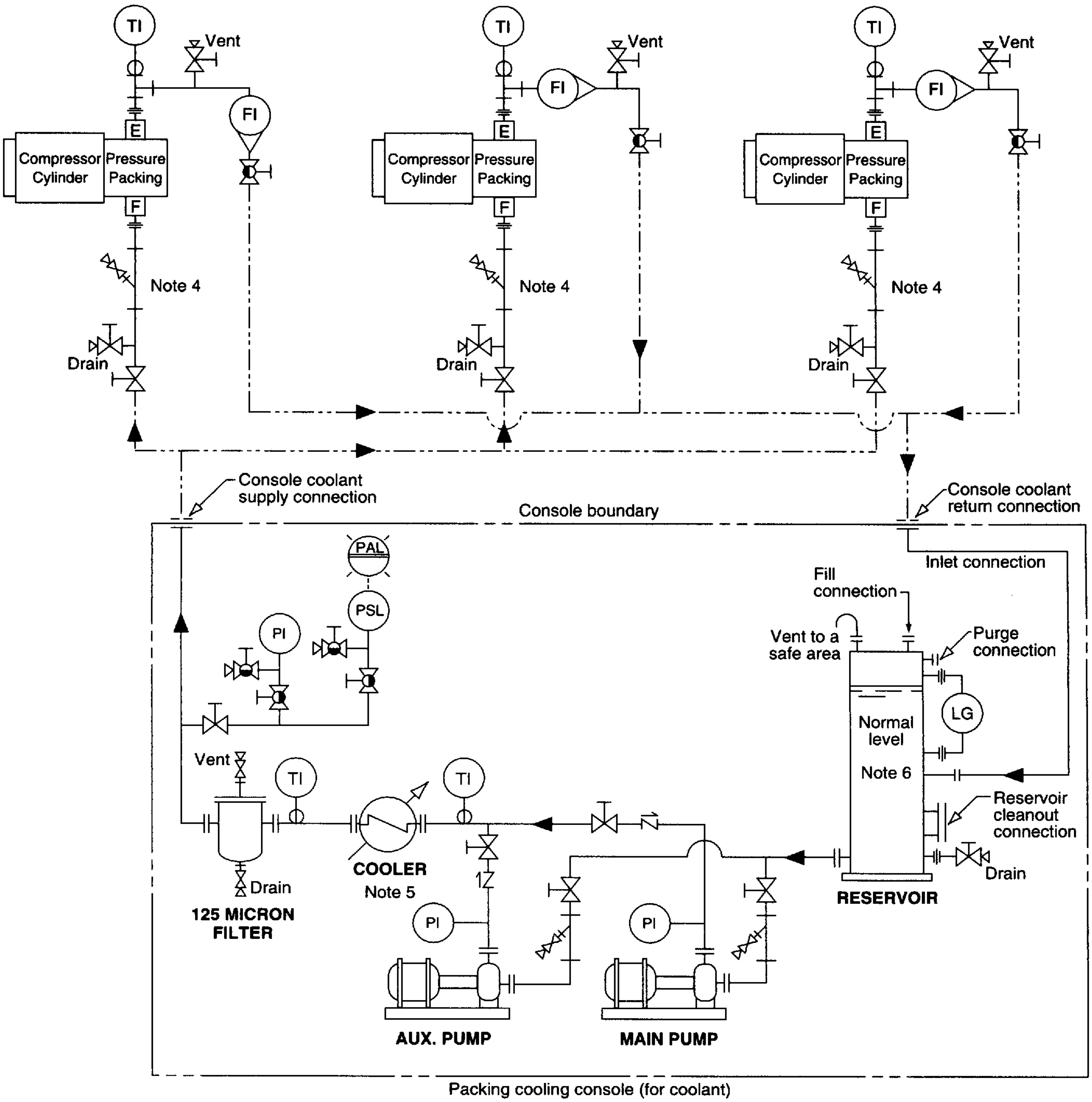
TYPE B
LONG SINGLE-COMPARTMENT DISTANCE PIECE
(SUFFICIENT LENGTH FOR OIL SLINGER TRAVEL)



TYPE D
SHORT TWO-COMPARTMENT OR DOUBLE DISTANCE PIECE ARRANGEMENT
(INBOARD DISTANCE PIECE OF SUFFICIENT LENGTH FOR OIL SLINGER TRAVEL)

3. The oil wiper packing may be located in the distance piece on the other side of the partition from that shown, and would be an integral assembly with the seal or buffer packing (1).
4. The intermediate seal or buffer packing (2) may be located in the outboard distance piece on the other side of the partition from that shown.

: and Packing Arrangements



Notes:

1. The instrumentation shown is the minimum required. The purchaser may wish to specify additional devices.
2. For cooling medium other than water, system design shall be mutually agreed upon between purchaser and the vendor.
3. See 2.11.
4. If a packing cooling console is not supplied, individual strainers are required (see 2.11.4.4).
5. Cooler to have vents and drains on both shell and tube side.
6. Normal level is above the highest point of the piping on the compressor cylinders.
7. The system shown is typical: more or less equipment may be provided.

Figure G-4—Typical Self-Contained Cooling System for Piston Rod Pressure Packing

Notes:
1. Instrumentation shown is the minimum required. The purchaser may wish to specify additional devices.
2. See 2.12.
3. Cooler to have vents and drains on both shell and tube side.
4. The system shown is typical: more or less equipment may be provided.
5. Check valve with RO on main pump is optional. The RO is for priming the main pump.
6. See 2.12.6.
7. Six-port continuous-flow transfer valve, manually operated.

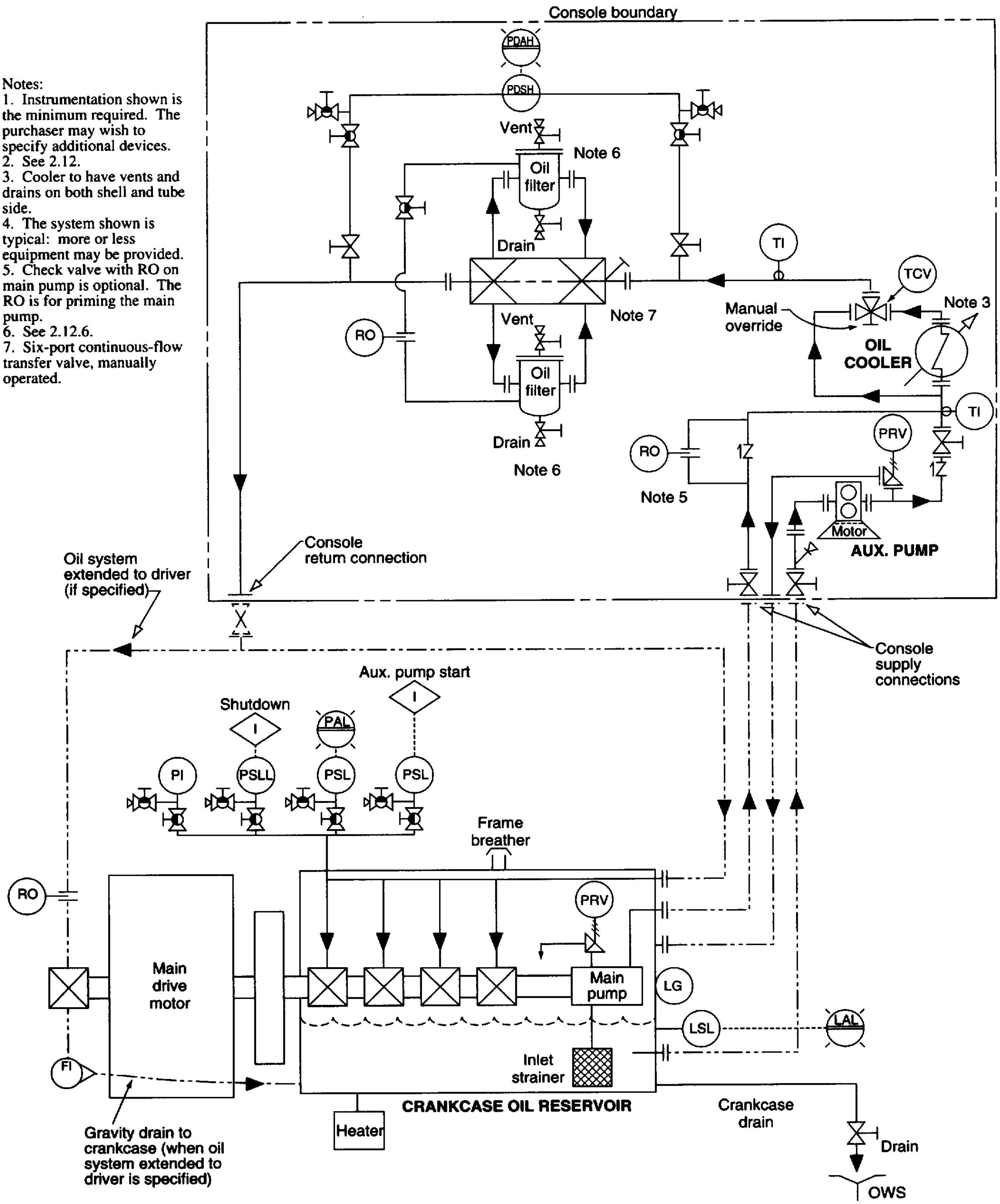


Figure G-5—Typical Pressurized Frame Lube Oil System

APPENDIX H—MATERIAL SPECIFICATIONS FOR MAJOR COMPONENT PARTS

Table H-1—Material Specifications for Reciprocating Compressor Parts

Part	Material	Form
Frame	Cast iron	Cast
Crankshafts	Steel	Forged
Connecting rods	Steel	Forged
Crossheads	Steel	Bar stock, forged, or cast
	Ductile iron[a]	Cast
Crosshead pins	Steel	Forged or bar stock
Distance pieces	Cast iron	Cast
Cylinders	Steel	Cast, forged, or fabricated
	Stainless steel	Cast or fabricated
	Nodular iron	Cast
	Gray iron	Cast
Cylinder liners	Steel	Tubing
	Stainless Steel	Cast
	Ni-resist	Cast
	Nodular iron	Cast
	Gray iron	Cast
Compressor cylinder heads	Steel	Cast, forged, or fabricated
	Stainless steel	Plate
	Nodular iron	Cast
	Gray iron	Cast
Pistons[b]	Steel	Forged, cast, bar stock, or fabricated
	Cast iron	Cast
	Aluminum	Forged or cast
Piston rods and tailrods[c]	Steel	Forged or bar stock
	Stainless Steel	Bar stock
Piston rod nuts	Steel	Forged or bar stock
	Stainless Steel	Forged or bar stock
Valve seats and guards	Steel	Plate or bar stock
	Stainless steel	Plate, bar stock, or cast
	Nodular iron	Cast or bar stock
	Cast iron	Cast
Valve plates	Stainless steel	Plate
	Non-metallic	Molded
Valve springs	Steel	Drawn
	Stainless steel	Formed
Packing cases	Steel	Bar stock
	Stainless steel	Bar stock
	Cast iron	Cast
Packing case flange	Steel	Forged, bar stock, or plate
Piston rings, wear bands, and packing rings	Metallic	Bronze
	Non-metallic[d]	Molded

[a]Ductile iron is acceptable in compressor frames nominally rated below 150 kilowatts (200 horsepower). See 2.9.6.
[b]Piston ring carriers for multi-piece pistons shall be furnished of wear resistant materials. See 2.8.3.
[c]Piston rods are normally coated with hard facing materials. Packing materials must be compatible with the rod coating. Selections should be agreed upon by the purchaser and the vendor for each specific service application. See 2.8.4.
[d]Typical filler materials include glass, carbon, bronze, and the like, in tetrafluoroethylene base material. The percentage of filler materials varies widely. Appropriate selections depend on the service application and the type of lubrication (nonlube, minilube, or full lube).

APPENDIX I—DISTANCE PIECE VENT, DRAIN, AND INERT GAS BUFFER SYSTEMS FOR MINIMIZING PROCESS GAS LEAKAGE

I.1 Scope

This appendix contains a general philosophy for the design of reciprocating compressor distance piece vent, drain, and inert gas buffer systems, which are typical of systems commonly used to minimize process gas leakage. This appendix is not intended to cover all possible situations; rather, it focuses on providing an approach which can be used to design successful systems.

Note: The piping, tubing, and components external to the distance piece may be supplied by either the purchaser or vendor. It is good practice for the vendor and purchaser to discuss the vent and drain system, and mutually agree on its design. See 2.10.5 and 2.10.6.

Instrument piping and valving details are not shown on typical schematics. Such requirements, including on-line testing requirements, shall be mutually agreed upon by the purchaser and vendor.

I.2 Legend For Schematics

The abbreviations and symbols used in the schematics in this appendix are defined in Appendix G.

I.3 The Purposes of Distance Piece Vent, Drain, and Buffer Systems

Distance piece vent and drain systems working in conjunction with packing and buffer systems accomplish several functions:

a. Confining and collecting the normal leakage from compressor rod pressure packing, and carrying the leakage to a safe location.
b. Preventing process gas leakage into the area around the machine.
c. Preventing contamination of the crankcase lube oil and the possible resulting bearing corrosion and/or degradation.
d. Atmospheric fugitive emissions control.
e. Confining and collecting large leakage in the event of compressor rod pressure packing failure, and directing the leakage to a safe location.
f. Helping to prevent a combustible atmosphere from developing in the crankcase.
g. Preventing excessive liquid accumulation in the distance piece.
h. Avoiding process gas leakage to sewer systems.
i. Allowing the operator to monitor and determine the condition of compressor rod packing.

I.4 Minimizing Process Gas Leakage

Figures I-2 and I-3 illustrate the arrangement of distance piece types that may be used when it is necessary to reduce the leakage of process gas to a minimum. The accompanying packing detail drawing (Figure I-1) shows the arrangement of the packing rings and the direction of flow and typical pressures of the buffer gas.

The wedge-type, side-loaded packing rings provide constant mechanical axial loading towards the sealing faces of the cups. This mechanical axial loading, added to a differential buffer gas pressure of at least 1 bar (15 pounds per square inch), higher than the disposal pressure holds the rings positively against their sealing faces minimizing buffer gas leakage and, at the same time, assures that the process gas that leaks past the cylinder pressure packing cups will be forced out into the disposal system (for example, flare) through the vent.

When proper differential buffer pressures are maintained, process gas leakage into the distance pieces is minimal; thus, process gas is prevented from entering the compressor frame. To minimize gas emissions, special packing should be specified (see 2.11.8).

I.5 Design Considerations

In addition to meeting the purposes described in I.3, the following factors should be considered when designing distance piece vent, drain, and buffer systems:

a. Small diameter vent and drain piping will tend to foul and corrode over time, inhibiting function. Consider using large (perhaps NPS 2) vent and drain headers, and corrosion-resistant materials.
b. On two-compartment distance piece systems, external cross connections between the inner and outer compartment vents and drains must be avoided.
c. On multiple machine systems, it should be possible to isolate each machine for maintenance.
d. Effective control of gas leakage requires the specification of gasketed solid metal covers on distance pieces (see 2.10.2).
e. Where vents, drains, liquid collection pots, and distance pieces are connected to disposal systems, such as flare or closed drain systems, these items should be designed to withstand the maximum disposal system pressure (for example, flare back pressure under relieving conditions). See 2.10.4.

Note: Distance pieces are typically designed for a maximum gauge pressure of 1.73 bar (25 psi). Special designs are required for higher pressures.

f. Typically, the common vent and drain from the pressure packing (connection G in Figures I-1, I-2, and I-3) will be carrying a mixture of liquid and gas. The system should be designed to separate these phases to avoid liquid blockage of the vent systems.

g. Leaks from the stems of valve unloaders and clearance pockets may also need to be collected and controlled. These can be integrated with the distance piece vent and drain systems.

h. There is concern about the reliability of check valves in safety situations, particularly in low-pressure systems such as distance piece vent and drain systems where there is a mixture of gas and liquids. Check valve use should be avoided, where possible.

i. Except for the pressure packing combined vent and drain, which is a pressure driven flow, separate vent and drain lines are necessary between the distance piece and liquid collection pot to pressure balance the system and allow free drainage. Sloped headers without pockets assist draining.

j. Large diameter tubing (Nominal Tubing Size [¾ inch OD] minimum) can be used between the individual distance pieces and the vent and drain headers. This usually results in a neat, easily-maintained installation compared to a piping system.

k. Manifolding and cross connections with drains and blowoffs from other equipment should be avoided.

l. The buffer gas purge pressure must be limited to the maximum allowable pressure for the distance piece components (see 2.10.4). Some buffer gas will flow into the compressor frame. Frame venting must allow an outlet for this flow (see Figure G-5).

m. Pneumatic trip systems internal to the frame (for example, crosshead pin temperature) should be energized with inert buffer gas rather than air to assist in maintaining the crankcase as an inert atmosphere.

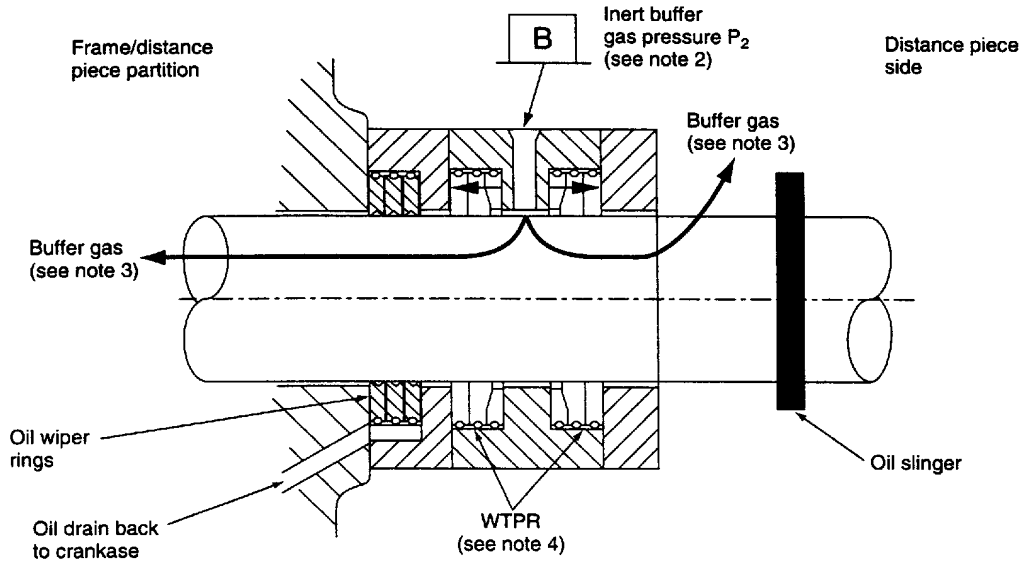
n. Effective establishment of an inert atmosphere in the crankcase will necessitate special maintenance safety procedures.

o. Where climatic conditions require, drains should be heat traced and insulated.

p. Under total packing failure, it should not be possible to over-pressure the distance piece (see 2.10.4 and 2.10.5). If the vent area is not sufficient, additional venting to a safe location by way of emergency pressure relief valves (PRVs) or spring-loaded pressure relief doors may be required.

q. Inert buffer gas purge rates are typically sized for a flow rate of 0.08 cubic decimeters per second (10 standard cubic feet per hour) per packing case. This may decrease as the packing seats in after the initial startup. Suggested flow meter range is 0.04–0.4 cubic decimeters per second (5–50 standard cubic feet per hour).

OIL WIPER PACKING WITH INERT BUFFER GAS PURGE



PRESSURE PACKING WITH INERT BUFFER GAS PURGE

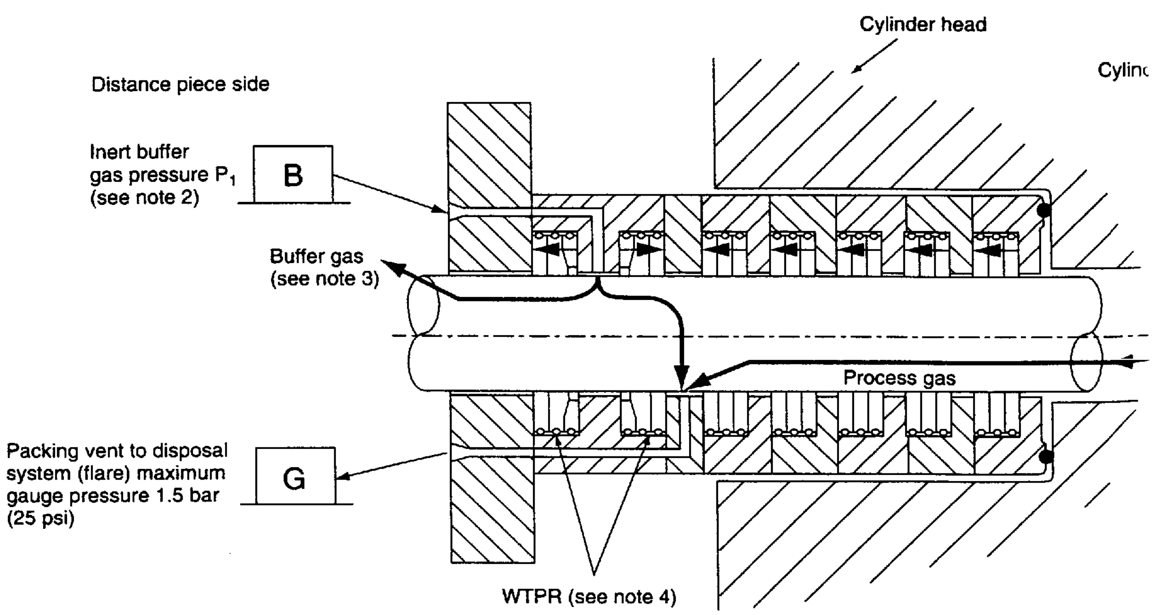
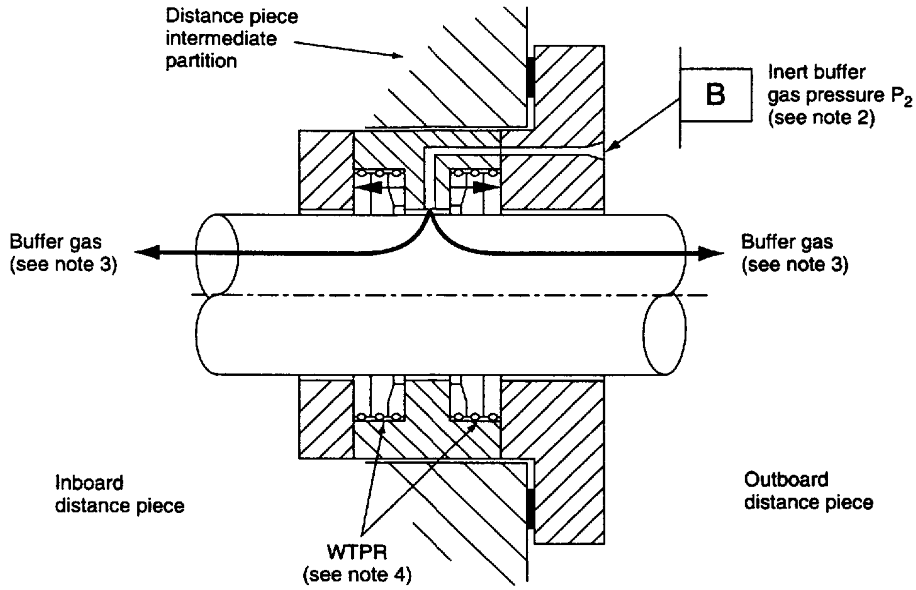


Figure I-1—Ty

INTERMEDIATE PARTITION PACKING WITH INERT BUFFER GAS PURGE
(Not Used With Type A & B Distance Pieces)

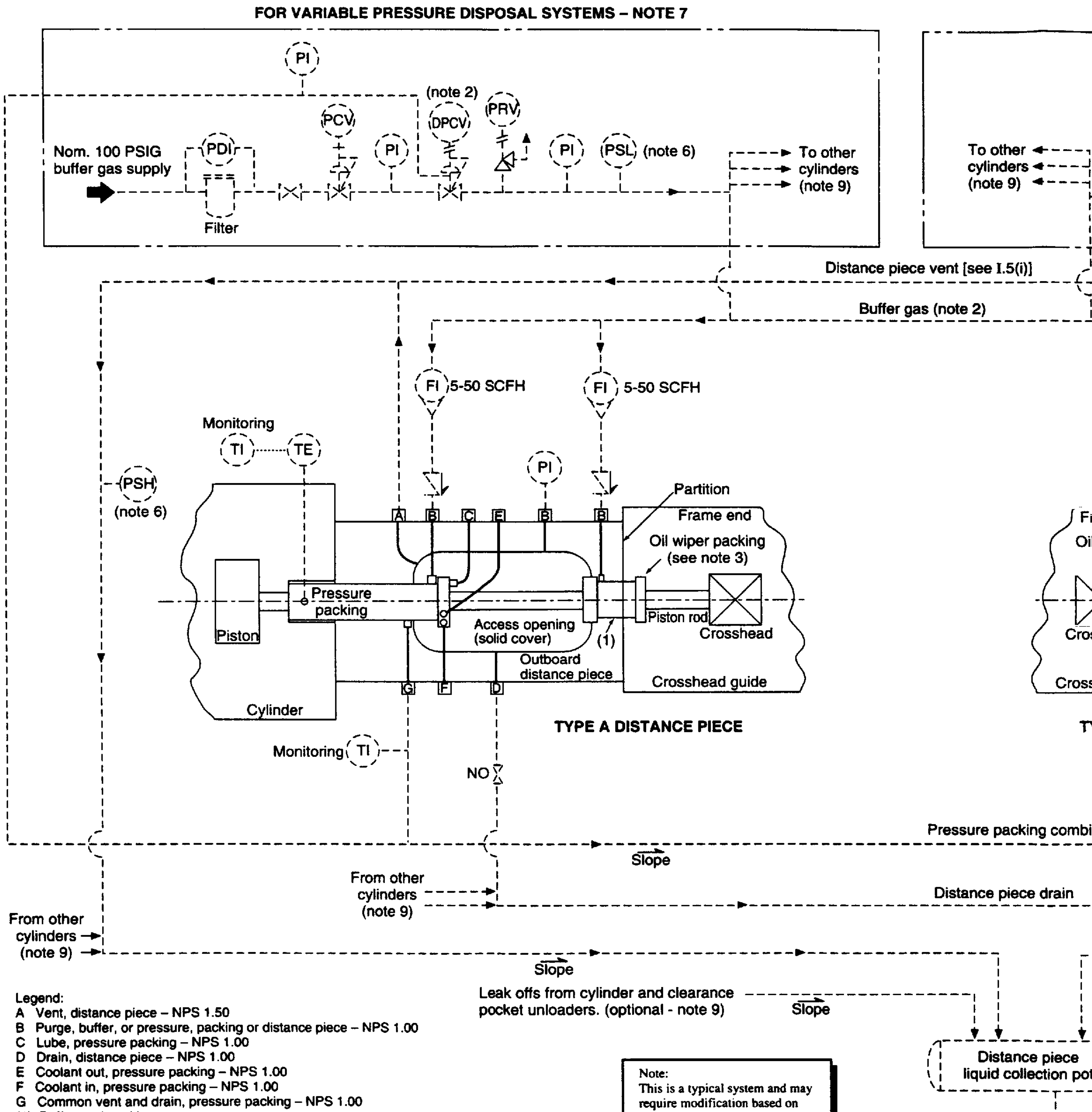


ıder side

Notes:
1. See 2.10.6 and 2.11.8.
2. Buffer gas pressure P_1 must be at least 1 bar (15 pounds per square inch) higher than the disposal system pressure at connection A or G (in the outboard distance piece) whichever is higher. Buffer gas pressure P_2 must be at least 1 bar (15 pounds per square inch) higher than the disposal system pressure at connection A (in the outboard distance piece). See Figures I-2 and I-3.
3. Under normal conditions, the buffer gas leakage rate is minimal. Under abnormal conditions (such as packing deterioration), a higher buffer gas leakage rate will occur.
4. WTPR = Wedge Type Packing Rings.
5. —▶ = Sealing face of packing cups.

Cylinder
gas pressure

ypical Purged Packing Arrangements



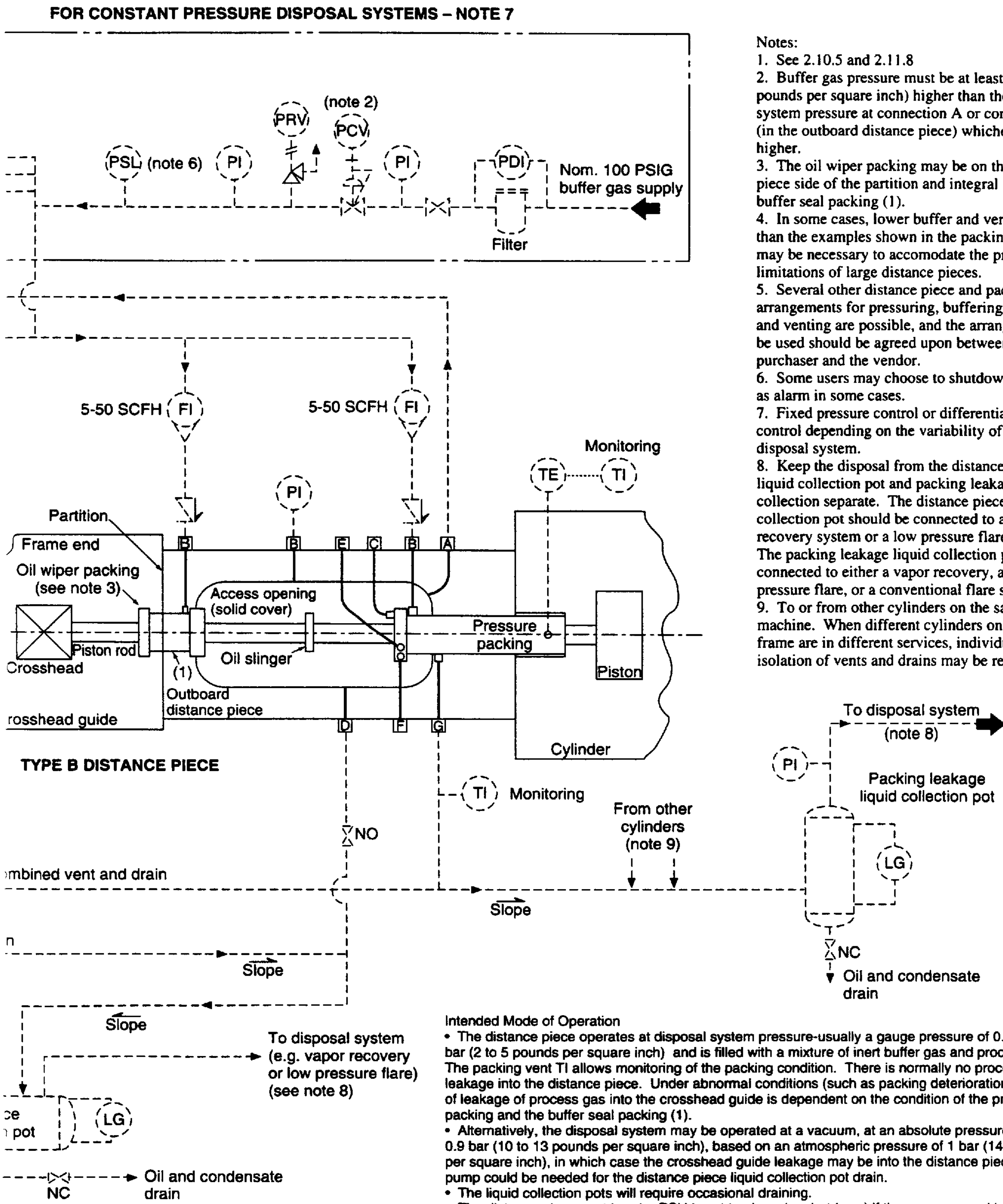
Legend:
A Vent, distance piece – NPS 1.50
B Purge, buffer, or pressure, packing or distance piece – NPS 1.00
C Lube, pressure packing – NPS 1.00
D Drain, distance piece – NPS 1.00
E Coolant out, pressure packing – NPS 1.00
F Coolant in, pressure packing – NPS 1.00
G Common vent and drain, pressure packing – NPS 1.00
(1) Buffer seal packing
(2) Intermediate partition packing

.... Electrical signal

Typically, all components external to distance piece or as shown in broken line ----- are furnished by purchaser.

Note:
This is a typical system and may require modification based on specific user requirements (see 11.1).

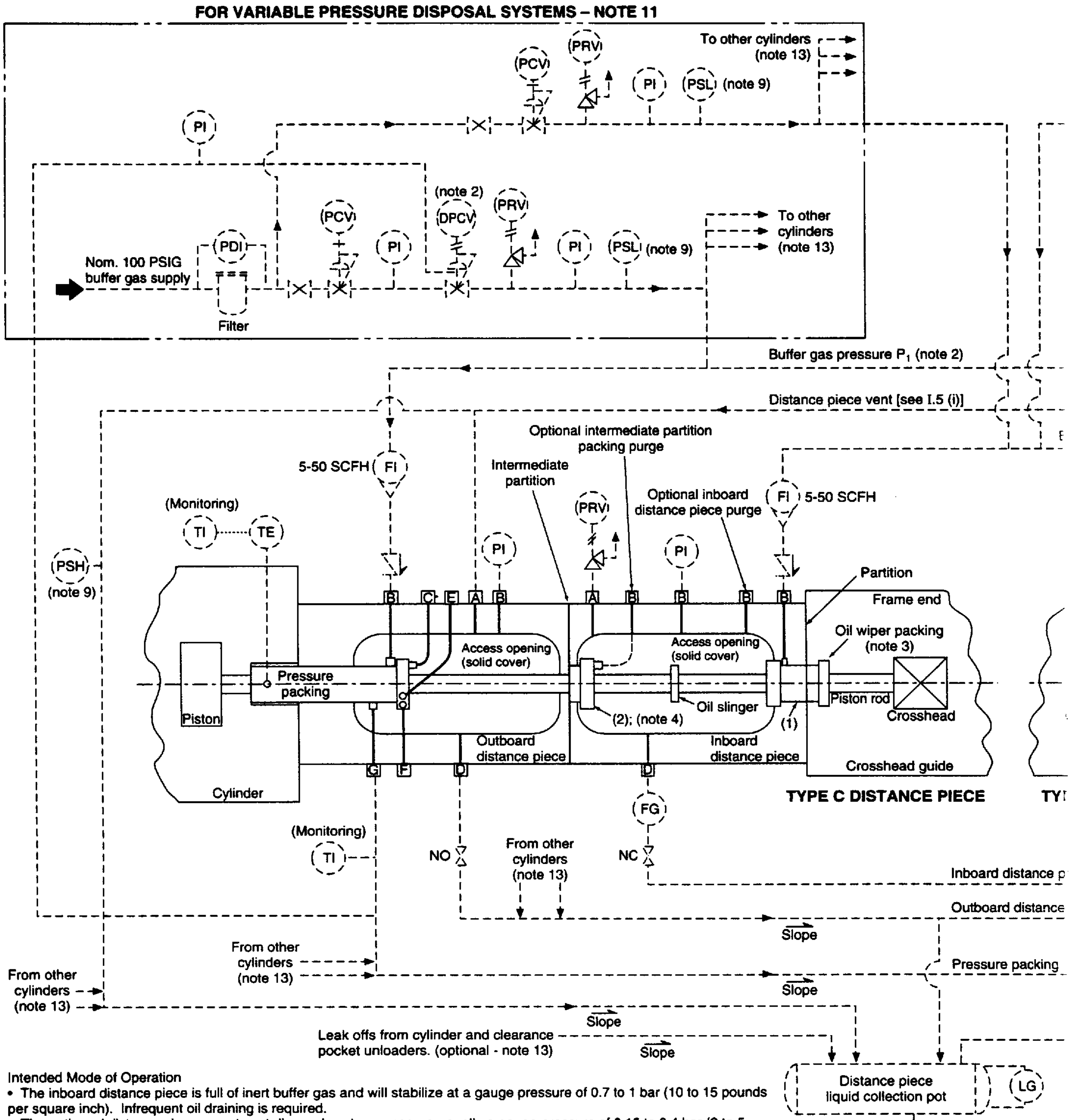
Figure I-2—Typical Buffered Single Compartr
Buffer Arrangement to Minimize



Notes:
1. See 2.10.5 and 2.11.8
2. Buffer gas pressure must be at least 1 bar (15 pounds per square inch) higher than the disposal system pressure at connection A or connection G (in the outboard distance piece) whichever is higher.
3. The oil wiper packing may be on the distance piece side of the partition and integral with the buffer seal packing (1).
4. In some cases, lower buffer and vent pressures than the examples shown in the packing details may be necessary to accomodate the pressure limitations of large distance pieces.
5. Several other distance piece and packing arrangements for pressuring, buffering, purging, and venting are possible, and the arrangement to be used should be agreed upon between the purchaser and the vendor.
6. Some users may choose to shutdown as well as alarm in some cases.
7. Fixed pressure control or differential pressure control depending on the variability of the disposal system.
8. Keep the disposal from the distance piece liquid collection pot and packing leakage liquid collection separate. The distance piece liquid collection pot should be connected to a vapor recovery system or a low pressure flare system. The packing leakage liquid collection pot can be connected to either a vapor recovery, a low pressure flare, or a conventional flare system.
9. To or from other cylinders on the same machine. When different cylinders on a common frame are in different services, individual isolation of vents and drains may be required.

Intended Mode of Operation
- The distance piece operates at disposal system pressure-usually a gauge pressure of 0.15 to 0.4 bar (2 to 5 pounds per square inch) and is filled with a mixture of inert buffer gas and process gas. The packing vent TI allows monitoring of the packing condition. There is normally no process gas leakage into the distance piece. Under abnormal conditions (such as packing deterioration), the rate of leakage of process gas into the crosshead guide is dependent on the condition of the pressure packing and the buffer seal packing (1).
- Alternatively, the disposal system may be operated at a vacuum, at an absolute pressure of 0.7 to 0.9 bar (10 to 13 pounds per square inch), based on an atmospheric pressure of 1 bar (14.7 pounds per square inch), in which case the crosshead guide leakage may be into the distance piece, and a pump could be needed for the distance piece liquid collection pot drain.
- The liquid collection pots will require occasional draining.
- The distance piece vent header PSH is set to alarm (or shutdown) if the pressure packing on one cylinder fails.

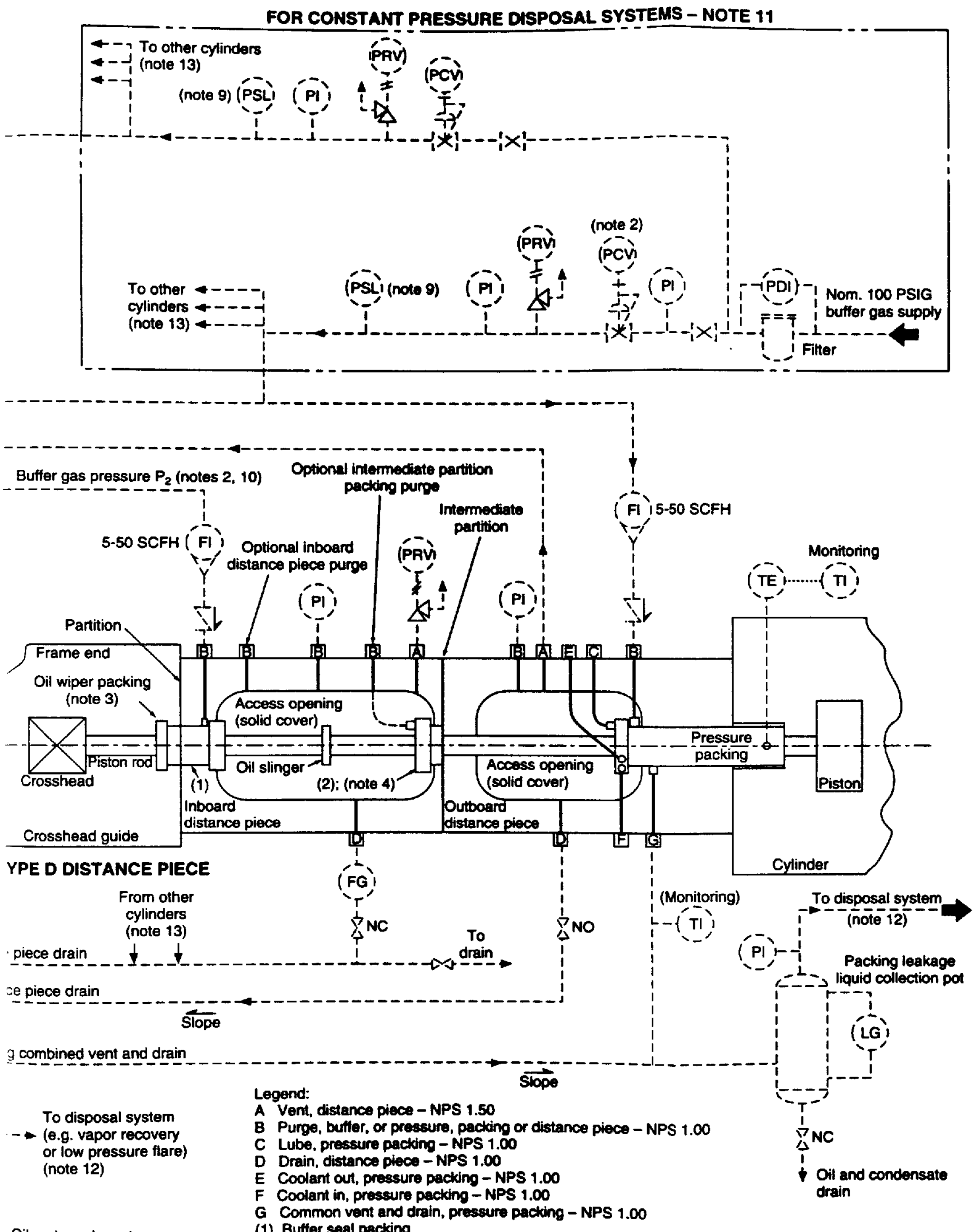
)artment Distance Piece Vent, Drain, and
ıize Process Gas Leakage



Intended Mode of Operation

- The inboard distance piece is full of inert buffer gas and will stabilize at a gauge pressure of 0.7 to 1 bar (10 to 15 pounds per square inch). Infrequent oil draining is required.
- The outboard distance piece operates at disposal system pressure-usually a gauge pressure of 0.15 to 0.4 bar (2 to 5 pounds per square inch) and is filled with a mixture of buffer gas and process gas. The packing vent TI allows monitoring of the packing condition. There is normally no process gas leakage into the distance piece. Under abnormal conditions (such as packing deterioration), the rate of leakage of process gas into the crosshead guide is dependent on the condition of the pressure packing, the intermediate partition packing (2), and the buffer seal packing (1).
- Alternatively, the disposal system may be operated at a vacuum, at an absolute pressure of 0.7 to 0.9 bar (10 to 13 pounds per square inch), based on an atmospheric pressure of 1 bar (14.7 pounds per square inch), in which case the crosshead guide leakage may be into the distance piece, and a pump could be needed for the distance piece liquid collection pot drain.
- The liquid collection pots will require occasional draining.
- The distance piece vent header PSH is set to alarm (or shutdown) if the pressure packing on one cylinder fails.

Figure I-3—Typical Buffered Tw
Buffer Arrangemen



Legend:
A Vent, distance piece – NPS 1.50
B Purge, buffer, or pressure, packing or distance piece – NPS 1.00
C Lube, pressure packing – NPS 1.00
D Drain, distance piece – NPS 1.00
E Coolant out, pressure packing – NPS 1.00
F Coolant in, pressure packing – NPS 1.00
G Common vent and drain, pressure packing – NPS 1.00
(1) Buffer seal packing
(2) Intermediate partition packing

.... Electrical signal

Typically, all components external to distance piece or as shown in broken line ----- are furnished by purchaser.

Notes:
1. See 2.10.5 and 2.11.8
2. Buffer gas pressure P_1 must be at least 1 bar (15 pounds per square inch) higher than the disposal system pressure at connection A or connection G (in the outboard distance piece) whichever is higher. Buffer gas pressure P_2 must be at least 1 bar (15 pounds per square inch) higher than the disposal system pressure at connection A (in the outboard distance piece).
3. The oil wiper packing may be on the distance piece side of the partition and integral with the buffer seal packing (1).
4. The intermediate partition packing (2) may be buffered in addition to the pressure packing in which case the inboard distance piece may be vented to the atmosphere.
5. In some cases, lower buffer and vent pressures than the examples shown may be necessary to accomodate the pressure limitations of large distance pieces.
6. Several other distance piece and packing arrangements for pressuring, buffering, purging, and venting are possible, and the arrangement to be used should be agreed upon between the purchaser and the vendor.
7. The orientation of the distance piece and packing flange/case connections may vary depending on the individual distance piece and the type of packing case used.
8. The intermediate partition packing (2) may be located in the outboard distance piece on the other side of the partition from that shown.
9. Some users may choose to shutdown as well as alarm in some cases.
10. Buffer gas may be fed either to the buffer seal packing (1) as shown, or directly into the inboard distance piece.
11. Fixed pressure control or differential pressure control depending on the variability of the disposal system.
12. Keep the disposal from the distance piece liquid collection pot and packing leakage liquid collection separate. The distance piece liquid collection pot should be connected to a vapor recovery system or a low pressure flare system. The packing leakage liquid collection pot can be connected to either a vapor recovery, a low pressure flare, or a conventional flare system.
13. To or from other cylinders on the same machine. When different cylinders on a common frame are in different services, individual isolation of vents and drains may be required.

Note:
This is a typical system and may require modification based on specific user requirements (see I1.1).

ʼwo Compartment Distance Piece Vent, Drain, and
ɔnt to Minimize Process Gas Leakage

APPENDIX J—RECIPROCATING COMPRESSOR NOMENCLATURE

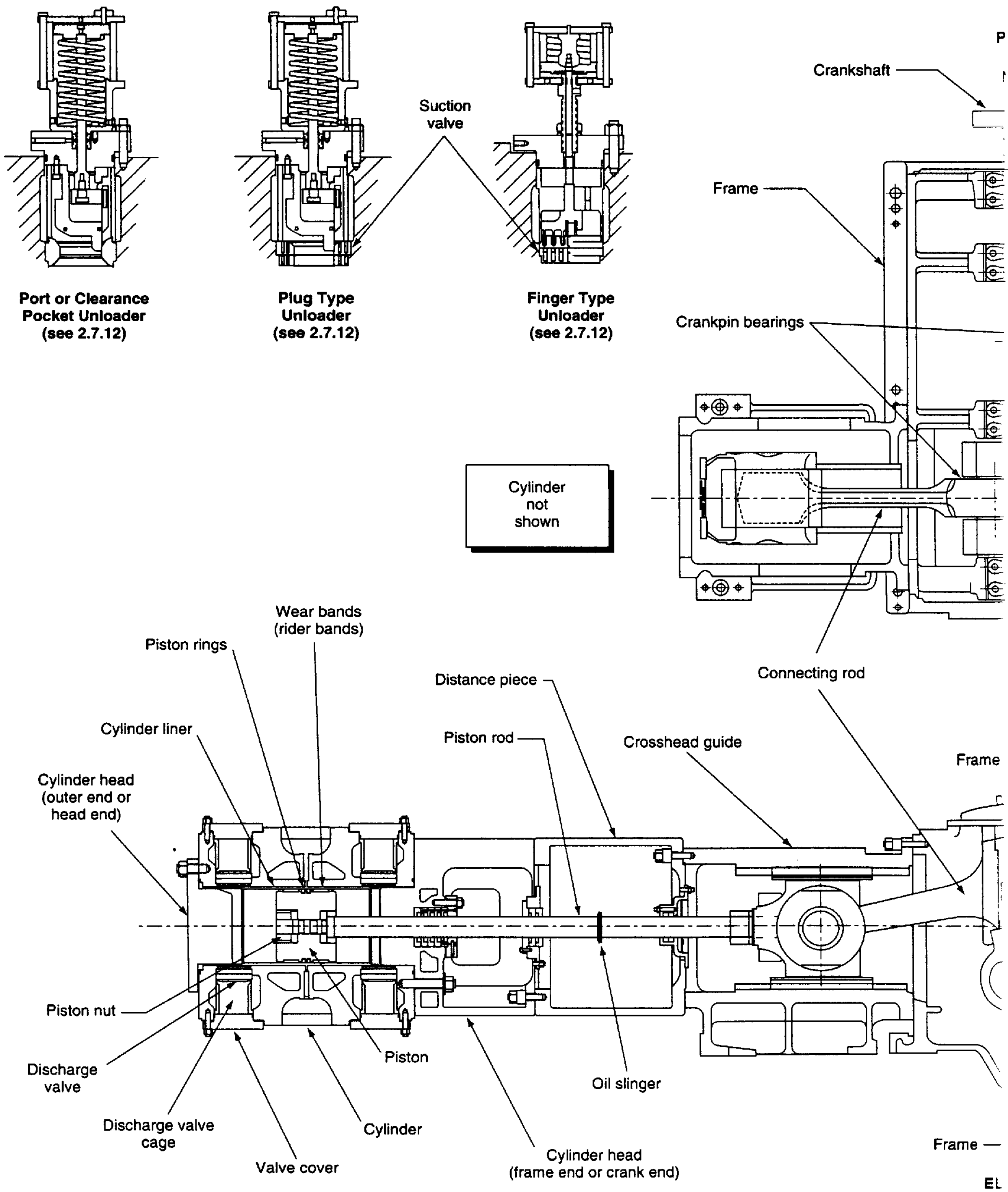
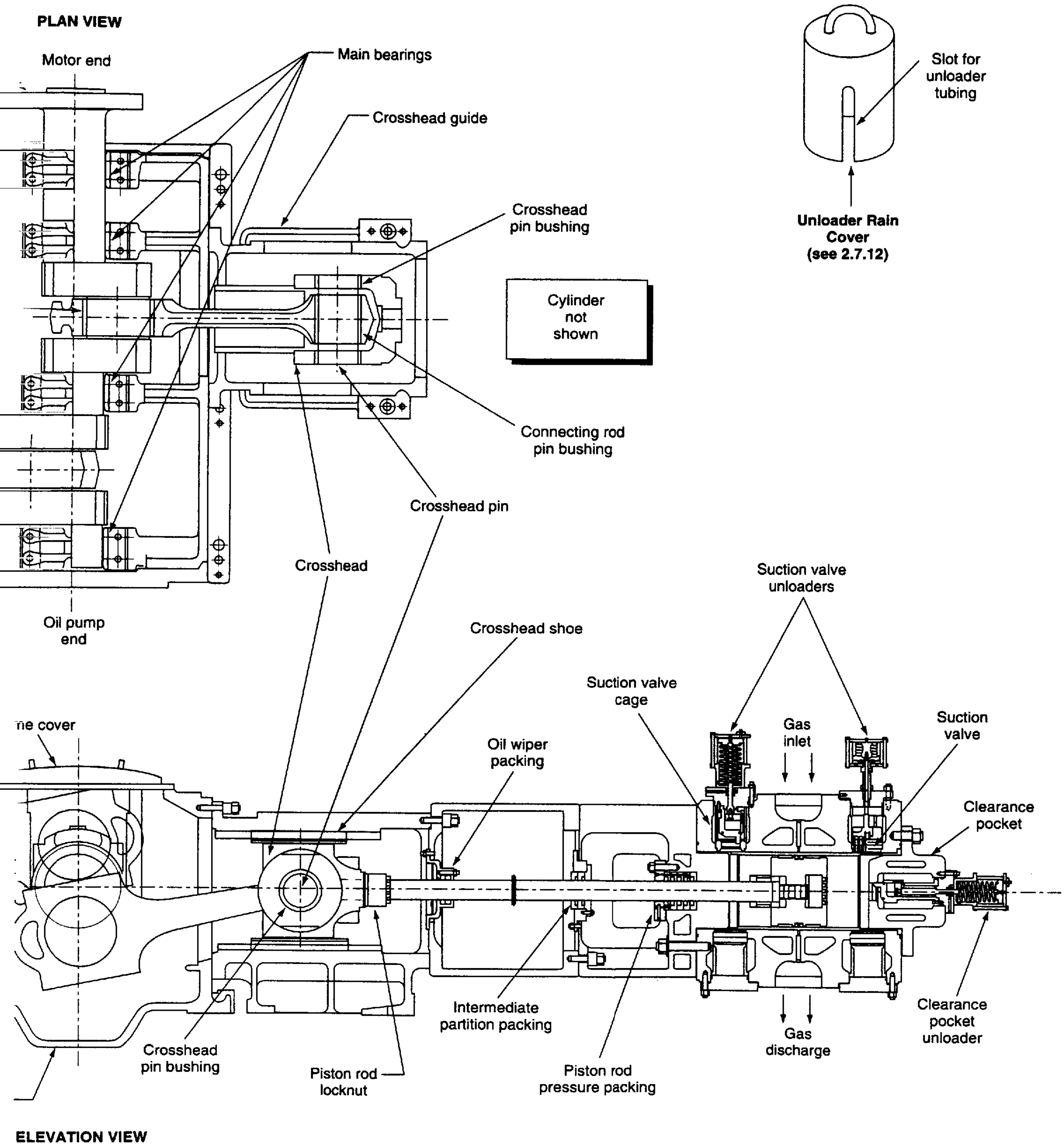


Figure J-1—Reciprocating (



; Compressor Nomenclature

APPENDIX K—INSPECTOR'S CHECKLIST

ITEM	REFERENCED PARAGRAPH API STD. 618	DATE INSPECTED	INSPECTED BY	STATUS
Material Inspection	4.2.2			
Crankshaft Ultrasonic Inspection	4.2.2.3.3			
Piping Fabrication and Installation	3.7.1.10 3.7.1.11 3.7.1.12			
Hydrostatic Test—Cylinders	4.3.2.1			
Hydrostatic Test—Piping and Vessels	4.3.2.1			
Gas Leakage Test	4.3.2.2			
Shop Test	4.3.3.1			
Bar-over Test Piston Rod Runout per Runout Table in Appendix C	4.3.4.1			
Cylinder Valve Leak Test	4.3.4.3			
Additional Tests—As Specified				
Crankshaft Web Deflection				
Examination of Internals for Cleanliness: Piping, Crankcase Pulsation Suppressors Coolers Filters Other				
Rotation Arrow	2.15.2			
Overall Dimensions and Connection Locations[a]				
Flange Dimensions and Finish[a]				
Anchor Bolt Layout and Size[a]				
Painting	4.4.3.2			
Corrosion Protection—Exterior	4.4.3.3 4.4.3.13			
Corrosion Protection—Interior	4.4.3.4 4.4.5			
Corrosion Protection—Lubricated Surfaces	4.4.3.5			
Closures of All Openings	4.4.3.6 4.4.3.7 4.4.3.8			
Equipment Nameplate Data	2.15.3			
Packing for Shipment	4.4.3.10			
Equipment Identification	4.4.3.11			
Piping Connections Identification (Tagging)	4.4.4			
Additional Inspections—As Specified				

[a]Check against certified drawings

APPENDIX L—TYPICAL MOUNTING PLATE ARRANGEMENT

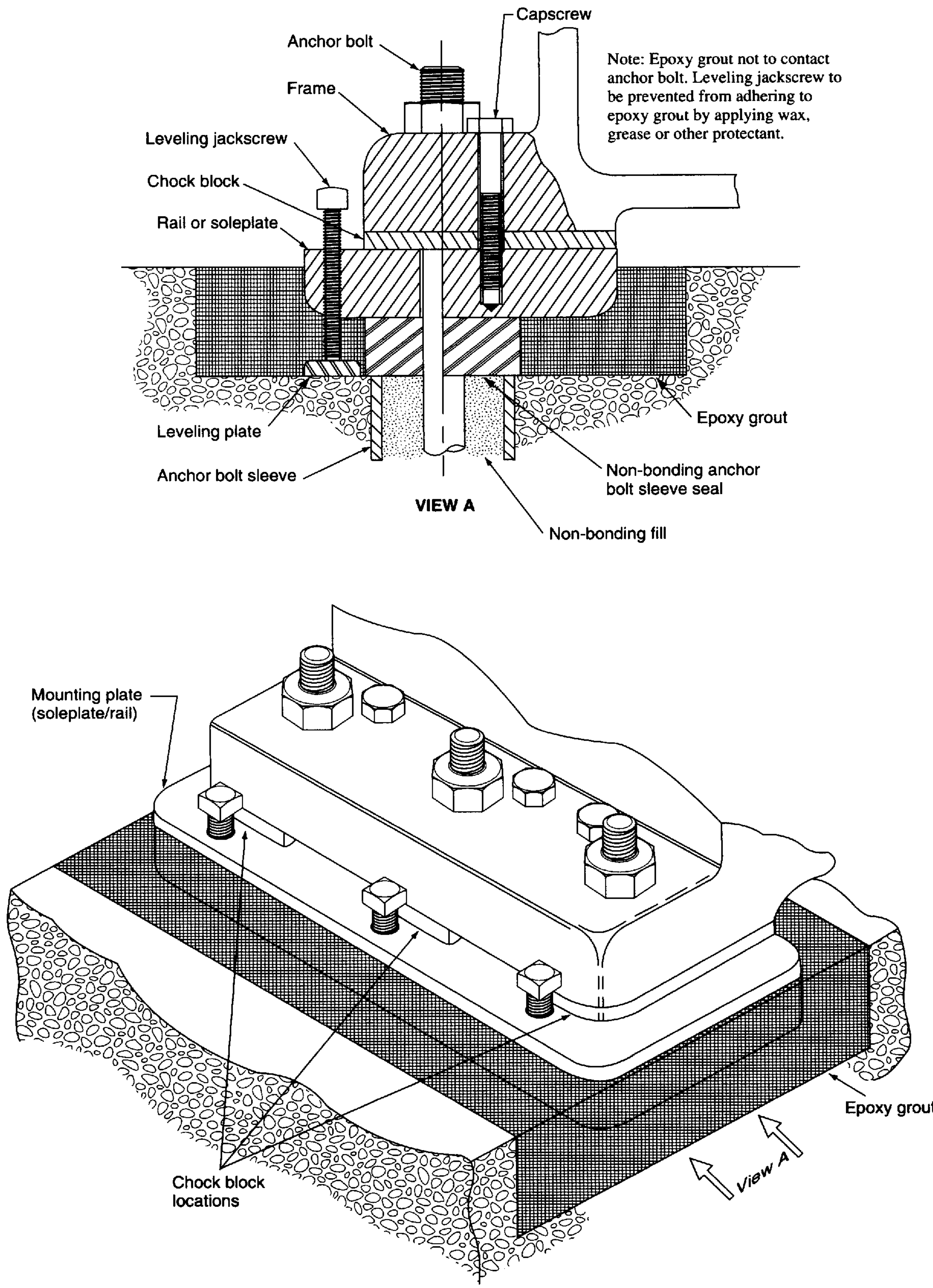


Figure L-1—Typical Mounting Plate Arrangement

APPENDIX M—PULSATION DESIGN STUDIES

This appendix contains a number of procedures that are used in conducting pulsation design studies. Three alternative design study approaches (as described in 3.9.2) are listed, and the procedures needed to meet the minimum requirements of each approach are described. They are:

Design Approach 1—includes M.1.
Design Approach 2—includes M.2 through M.4.
Design Approach 3—includes M.2 through M.8.
Optional—are M.9 through M.11.

M.1 Analytical Study

This study comprises two parts:

a. Design of compressor pulsation suppression devices using proprietary and/or empirical analytical techniques to meet pulsation levels specified in 3.9.2.5. Acoustical simulation is not required; however, without an acoustical simulation, it is not possible to know whether or not the specified levels will be met.
b. A simplified analysis of the purchaser's piping system to determine critical piping lengths that may be in resonance with acoustical excitation frequencies.

M.2 Acoustical Analysis (Acoustical Simulation Study)

This study consists of using modeling techniques which account for the acoustical interaction between the compressor and piping. The modeling method must account for the dynamic interaction of flow through the valves and the dynamic pressure variation in the cylinder and in the cylinder passages immediately outside of the valves. Variations in specified operating conditions shall be analyzed by extending the analysis above and below the specified operating conditions. This is normally accomplished by simulating speeds above and below the specified speed(s). This step may include a passive piping analysis to determine the acoustical response of the piping. The piping system must be modeled to a point where piping changes will have insignificant effects on the parts of the system under study (usually a large vessel upstream and downstream of the units to be studied). The pulsation analysis study must produce the following information:

a. Prediction of Pulsation Levels: operating conditions and compressor loading steps are chosen to yield the highest expected pulsation amplitudes throughout the piping system. Pulsation amplitudes are then compared to the levels identified in 3.9.2.7 and 3.9.2.2.3.
b. Calculation of Pulsation-Induced Shaking Forces (Unbalanced Forces): predict the maximum pulsation-induced shaking forces and unbalanced pressure acting on the critical elements of the piping system such as pulsation suppression devices, pulsation suppression device internals, vessels, closed end headers, etc.
c. Development of Piping Modifications: if the pulsation analysis indicates that pulsation levels and/or shaking forces are too high, modifications to the pulsation suppression devices and/or piping systems will be made and the analysis continued until the system meets the guidelines defined in 3.9.2.7 and 3.9.2.2.3.

M.3 Performance Analysis (Pulsation and Pressure Drop Effects)

a. Pressure drops are calculated through each pulsation suppression device and compared to the levels identified in 3.9.2.2.4.
b. The effects of dynamic interaction between compressor cylinders, pulsation-suppression devices and attached piping on cylinder performance are evaluated and pulsation-induced horsepower and capacity deviations are determined for the recommended design. This analysis shall optimize pulsation-related compressor performance.

M.4 Mechanical Piping System Analysis

This study calculates the mechanical natural frequencies of the individual piping spans using published frequency factors, nomograms, etc., to ensure that the piping span natural frequencies are detuned from significant pulsation excitation harmonics. From this analysis the piping supports, clamp type, planes of restraint and their locations are recommended. Thermal flexibility effect should be considered in the clamp designs and anchoring systems. Generally, the clamp and support stiffness should be at least twice the basic piping span stiffness to ensure a vibratory node at the clamp.

M.5 Mechanical Compressor Manifold System Analysis

This study calculates the mechanical natural frequencies and mode shapes of the cylinder manifold system. The analysis involves modeling the properties of the crosshead guide(s), distance pieces(s), cylinder(s), flange(s), compressor nozzle(s), branch connection(s), pulsation suppression devices and inlet and outlet piping. For accurate results, the modeling process should consider the significant mechanical components' properties (such as gasket flexibility, clamp stiffness, shell deflections of the pulsation suppression device, etc.) that influence the response.

M.6 Compressor Manifold System Vibration and Dynamic Stress Analysis

The significant pulsation-induced forces are applied to the mechanical model of the compressor manifold system. The vibration and dynamic stresses at the critical points in the system are compared to the levels identified in 3.9.2.2.1. The cylinder gas loads as determined by 2.4.3 should be considered in the evaluation of dynamic stresses. The analysis shall be carried out to the extent required to obtain meaningful information for a given design and shall be justified in the report.

M.7 Piping System Dynamic Stress Analysis

A piping system dynamic stress analysis calculates the mechanical system responses and associated mode shapes. The significant predicted pulsation forces are imposed on the piping to the extent necessary in order to calculate the expected vibration and stress amplitudes at the critical points in the system. These stresses are compared to the levels identified in 3.9.2.2.1.

M.8 Calculation of Dynamic and Static Stresses on Pulsation Suppressor Internals

This study applies pulsation-induced shaking forces and pressure-induced static forces to the shell and vessel internals and computes stress levels to satisfy 3.9.2.2.1.

M.9 Compressor Valve Dynamic Response Study

This study calculates dynamic response of the valve spring and sealing element including interaction with the piping and compressor cylinder gas passage induced pulsations. It evaluates the pulsation-related effects on compressor performance and valve efficiency, reliability, and life. The valve dynamic model shall include all items as required in 2.7.9.

M.10 Pulsation Suppression Device Low Cycle Fatigue Analysis

When required by Division 2 of the ASME code, this analysis is used to predict the stresses from thermal gradients, thermal transients, and pressure cycles on the pulsation-suppression devices and internal components. The stresses are compared to ASME-code allowables.

M.11 Piping System Flexibility

This analysis predicts the forces and stresses resulting from thermal gradients, thermal transients, pipe and fitting weights, static pressure, and bolt-up strains. These stresses are compared to the levels identified in the applicable ANSI code. Modeling includes frame growths and component properties listed in M.6.

APPENDIX N—GUIDELINE FOR COMPRESSOR GAS PIPING DESIGN AND PREPARATION FOR AN ACOUSTICAL SIMULATION ANALYSIS

N.1 General

N.1.1 Any reciprocating compressor in conjunction with a piping system forms an interactive dynamic system that cannot be accurately analyzed as two separate systems. Therefore, it is virtually impossible for the pulsation system designer and the piping system designer to arrive independently at proposed designs that can be guaranteed to work and be cost effective.

N.1.2 Section 3.9 of this standard defines the technical requirements placed on the pulsation control system designer. This appendix (Appendix N) gives the piping system designer guidelines that will help minimize the problems that can occur at the time of the acoustical simulation; it also outlines the information that must be available at the time of this interactive analysis. Communication among the piping system designer, the compressor vendor, and the pulsation control system designer during the course of a project is important to minimize problems and develop the best overall compressor system installation. The key times of interaction are at the post order coordination meeting (see 5.1.3), early in the project, and during the interactive acoustical simulation/mechanical analysis.

N.1.3 The purchaser may elect to perform an in-house acoustical simulation, to use equipment vendors' services, or to use the services of a third party.

N.2 Acoustical Consideration in Piping Designs

N.2.1 The interaction of the compressor, pulsation devices, and piping system produces potentially harmful pulsations when there is resonant interaction among the various elements in the system. The system designer can help to minimize this interaction by avoiding resonant lengths of pipe. When resonant lengths of pipe are used, and the resonant frequency matches compressing frequency, one can expect major changes to the system as a result of the acoustical simulation analysis. The resonant length of various piping configurations is given in the following equation. It is recommended that lengths of these configurations be avoided in a ± 10 percent band for the first four harmonics of compressor speed. The piping areas where this is most important are the sections of piping between the first major volume on the suction side and the first major volume on the discharge side. In piping areas outside major volumes, or those far enough away from the compressor(s), the potential for harmful pulsation buildup is considerably reduced.

N.2.2 For piping sections open at both ends or closed at both ends the length to be avoided can be calculated from the following:

$$L_H = \frac{30 \times C}{n \times N}$$

Where:

L_H = pipe length to be avoided in meters (feet).
C = velocity of sound in gas in meters/second (feet/second).
n = harmonic number (1, 2, 3, and 4).
N = compressor speed in revolutions per minute.

Examples of this are lengths between major volumes, length of headers, etc.

N.2.3 For pipe sections open at one end and closed at the other end, the lengths to be avoided can be calculated from the following:

$$L_Q = \frac{15 \times C}{n \times N}$$

Where:

L_Q = pipe length to be avoided in meters (feet).
C = velocity of sound in gas in meters/second (feet/second).
n = harmonic number (1, 2, 3, and 4).
N = compressor speed in revolutions per minute.

Examples of this are relief valve lines and bypass lines.

Note : Pipe diameter changing from a small to a larger size can be considered an open end when the diameter change is 2 to 1 or more. Similarly, pipe diameter changes from a larger to a smaller diameter can be considered a closed end when the diameter change is 2 to 1 or more.

N.2.4 After the piping design has been completed, the mechanical constraints have been initially located, and the pipe stresses are found to be acceptable, the design must be checked with an acoustical simulation.

N.2.5 For variable speed compressors and/or those with varying gas composition, and/or varying pressures and temperatures, the separation of resonances is more difficult to calculate and can only be handled properly with an acoustical simulation study.

N.3 Acoustical Simulation Overview

N.3.1 The extent of the piping system to be analyzed by acoustical simulation techniques is usually defined as all associated piping systems to a point where piping changes will have only insignificant effects on the parts of the system under study and in determining the acoustical characteristics of the design. Typically, these requirements are satisfied by beginning the simulation with the inlet of a major process vessel or volume on the suction side of the compressor unit(s), continuing through all interstage systems (if any), and terminating the study at the outlet of a major process vessel or volume on the discharge side of the unit(s). Included are lateral lines to or from this system, such as relief valve lines and bypass lines.

N.3.2 When major volumes do not exist or are very remote from the compressor, suitable piping lengths are included in the simulation, such that the pulsation levels are sufficiently low so as to minimize the potential of pulsation-driven vibration problems.

N.4 Information Required

N.4.1 A considerable amount of information is required for the proper performance of an acoustical simulation. The purchaser, or his representative, normally serves as coordinator to see that the information is available.

N.4.2 The following pieces of information are required from the system designer:

N.4.2.1 Data sheets showing all compressor operating conditions, analysis of all gases to be compressed, and steps of unloading.

N.4.2.2 Isometric drawings showing all lengths (between bends, valves, diameter changes, etc.) and line sizes and schedules for the complete piping system, including all branch lines and relief valve lines. If a mechanical study is included, the distance between the supports and the type of support and clamp used at each location must be shown on the isometrics. A detailed drawing of each type of support and clamp is required.

N.4.2.3 Piping and Instrument Diagrams (P&IDs) are required to ensure that all piping and equipment that may affect the study are included.

N.4.2.4 Layout drawings are required to help determine the practicality of any proposed modifications. Reproducible drawings are useful since they can be marked up, copied, and included in the report.

N.4.2.5 Complete information must be supplied on all of the piping up to and including the first large volume in the suction, the interstage, and the discharge piping. Every branch must be included up to a shutoff valve or a large volume.

N.4.2.6 Any orifice or other flow-resistive device must be shown and complete details provided.

N.4.2.7 Detailed drawings of each vessel, showing the location of all nozzles, the internal diameter, and the length, as well as details of any vessel internals are required. Normal liquid levels and design pressure drops in these vessels must be shown.

N.4.2.8 TEMA data sheets, or their equivalent, must be provided for all heat exchangers. The data sheet must show whether process gas is in the tubes or in the shell; the number, length, and gauge of the tubes; whether the tubes are plain or finned; the number of passes; the I.D. of the shell; the gas temperature in and out; the gas pressure drop; and the dimensions of the header. A dimensional drawing is preferred.

N.4.2.9 If there are different process gas routings, a complete description must be included to show the relative positions of all the valves for each routing. If different process gases are involved, the description must show which routings apply to which gases. Flow from/to any sidestream must be shown, including gas analysis, flow rate, and direction.

N.4.2.10 If gas filters are used, the type of filter, internal diameter, length, and element pressure drop must be supplied. A dimensional drawing is preferred.

N.4.2.11 When two or more compressors are connected to the same piping system, a clear description of how they will operate (such as loading steps, speed differences, etc.) is required.

N.4.3 The following information is required from the pulsation suppressor vendor: detailed dimensional drawings on each suppressor showing the location of all nozzles, lengths, internal diameters, and details on suppressor internals, if any.

N.4.4 The information in Table N-1 is required from the compressor vendor.

N.4.5 It is highly recommended that a piping system design representative who is familiar with the piping system be present at the acoustical simulation analysis, in order to make piping changes as the need arises.

Table N-1—Compressor Data Required for Acoustic Simulation

Compressor Data	Design Approach	
	2	3
Compressor data		
Head end fixed clearance volume	x	x
Head end unloader volume (s)	x	x
Crank end fixed clearance volume	x	x
Crank end unloader volume (s)	x	x
Casting drawings		
Compressor cylinder (internal passage)	x	x
Distance piece (inertia-stiffness)		x
Crosshead guide (inertia-stiffness)		x
Assembled cylinder weight		x
Support drawings		
Cylinder support drawings		x
Crosshead guide support drawings		x
Distance piece support drawings		x
Pulsation suppressor support drawings		x
Compressor valve data		
Number of valve assemblies		x
Type of valves		x
Number of valve elements per assembly		x
Valve lift		x
Weight per element		x
Spring pre-load per element		x
Spring rate per element		x
Full projected area per element lift area		x
Effective full lift flow area per assembly		x
Crank angles between manifolded cylinders		x

APPENDIX O—GUIDELINES FOR SIZING LOW PASS ACOUSTIC FILTERS

O.1 General

The general configuration for an acoustic filter is shown in Figure O-1.

The lowest acoustical resonant frequency of the filter system is referred to as *Helmholtz frequency* (f_H). An accepted generalized equation for Helmholtz frequency is:

$$f_H = \frac{1c}{2\pi}\left(\frac{\mu}{V_1}+\frac{\mu}{V_2}\right)^{1/2} \quad (1)$$

Where:

f_H = Helmholtz frequency in hertz.
c = velocity of sound in gas in meters per second (feet per second).
V_1 = volume of cylinder bottle (chamber) in cubic meters (cubic feet).
V_2 = volume of filter bottle (chamber) in cubic meters (cubic feet).
μ = acoustical conductivity in meters or feet.

Where:

$$\mu = \frac{A}{L_c + 1.2D_c} = \frac{A}{L}$$

A = internal cross-sectional area of choke in square meters (square feet).
L_c = actual length of choke in meters (feet).
L = acoustic length of choke in meters (feet).
D_c = diameter of choke in meters (feet).

The *filter cut-off frequency* (f_{co}), which is the frequency above which pulsation attenuation is achieved, is usually defined as follows:

$$f_{co} = \sqrt{2} f_H$$

The acoustic filter can be either symmetrical or nonsymmetrical. As shown in the Figure O-1 and Equation 1, the nonsymmetrical filter can have different volumes (lengths and diameters) and a different length of choke. For a symmetrical filter, the volumes are equal and the acoustical length of the choke L is equal to the length of each volume. This also means that the diameter of each volume is equal.

Substituting into Equation 1 for symmetry, the Helmholtz frequency for a symmetrical filter becomes:

$$f_H = \frac{1}{\sqrt{2}}\frac{c}{\pi}\frac{D_c}{LD_B} \quad (2)$$

Where:

D_B = diameter of bottles in meters (feet).

O.2 Guidelines

Unless otherwise specified and agreed upon, the following guidelines are to be used for the preliminary sizing of acoustic filters.

O.2.1 SELECTION OF HELMHOLTZ FREQUENCY

The preferred Helmholtz frequency is:

$$f_H = \frac{rpm}{85}$$

Where:

rpm = compressor speed in revolutions per minute.

Only when conditions are such that it is uneconomical, or physically impractical, should a higher Helmholtz frequency be considered: that is, only when pressure drop is very critical - as in the case of low suction pressure, or when space is limited by the compressor system layout. In that instance, a higher Helmholtz frequency may be chosen. Generally, the Helmholtz frequency should not be higher than:

$$f_H = \frac{rpm}{45}$$

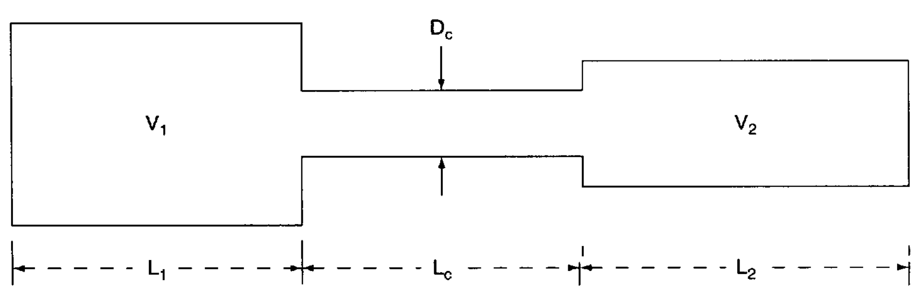


Figure O-1—Nonsymmetrical Filter

unless the acoustic simulation proves otherwise. For compressor speeds above 500 rpm, the Helmholtz frequency should not exceed:

$$f_H = \frac{rpm}{85}$$

O.2.2 RELATIONSHIP OF FILTER ELEMENT DIAMETERS

The diameter of the cylinder bottle (chamber) V_1 should be equal to, or greater than, two times the diameter of the cylinder connection (flange).

The diameter of the filter bottle (chamber) V_2 should be equal to, or greater than, three times the diameter of the line piping.

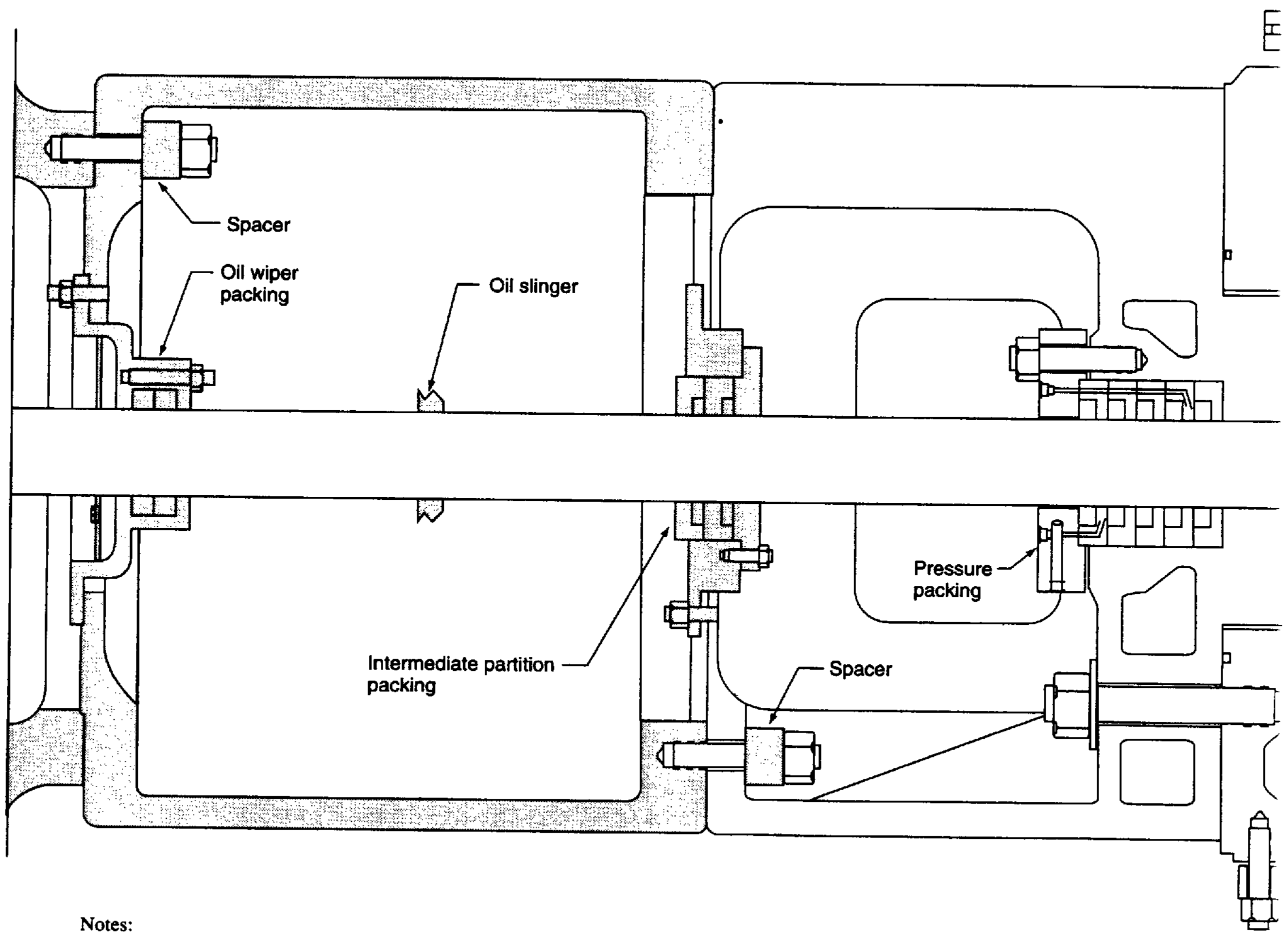
O.2.3 RELATIONSHIP OF FILTER ELEMENT LENGTHS

The preferred filter system is with equal lengths of cylinder bottle (chamber), choke tube, and filter bottle (chamber). In cases where the physical restraints (piping layout) and the required sizes do not permit equal lengths, the next best alternative is with equal length of choke and filter (chamber).

O.2.4 SIZING OF THE DIAMETER OF THE CHOKE TUBE (D_c)

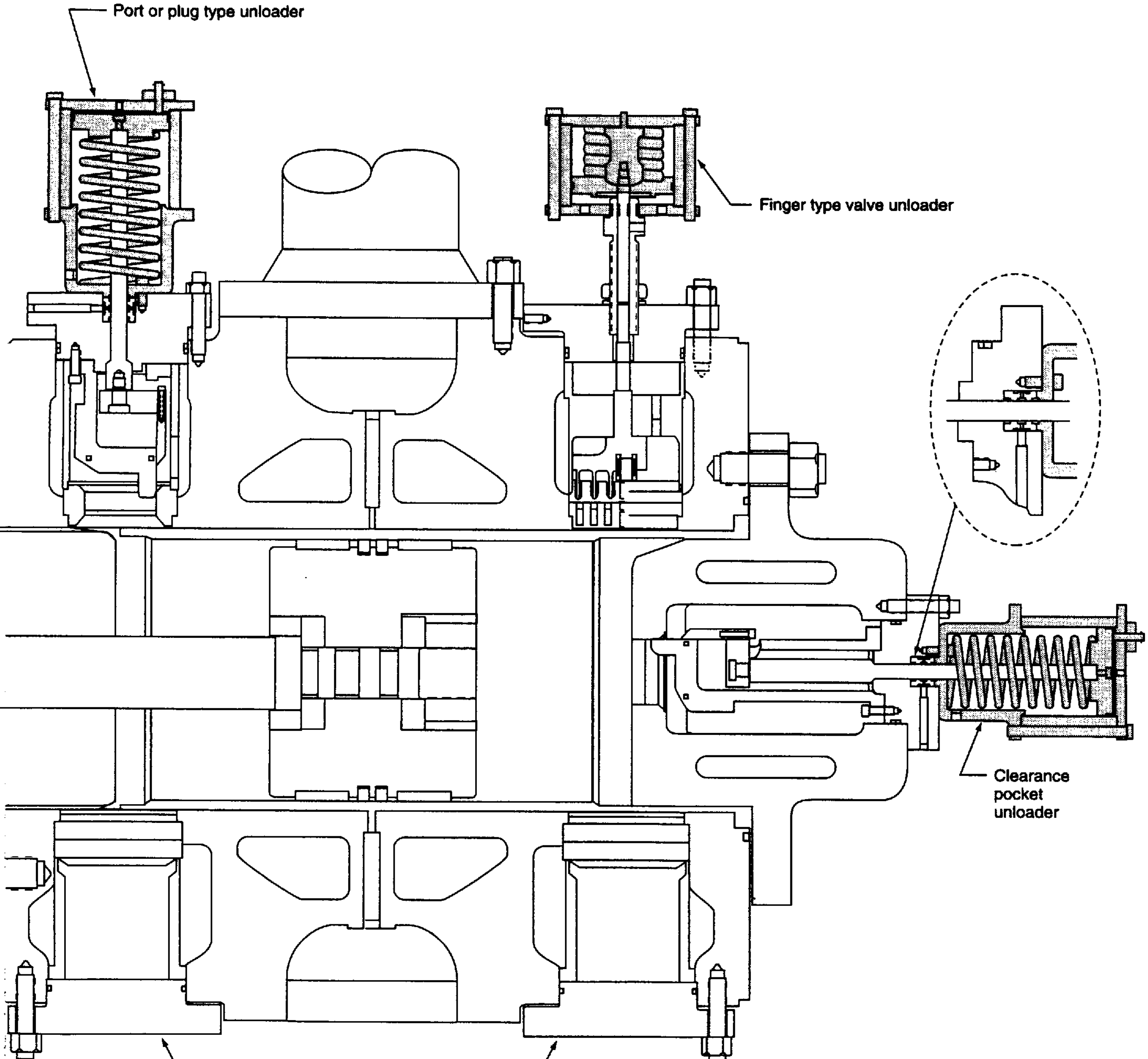
Unless otherwise specified, calculate the maximum allowable pressure drop per the applicable equation in 3.9.2.2.4. Using maximum allowable pressure drop and appropriate pressure drop relationships, calculate the minimum diameter choke tube which can be used considering all operating conditions expected.

APPENDIX P—MATERIAL GUIDELINES FOR COMPRESSOR COMPONENTS—COMPLIANCE WITH NACE MR0175



Notes:
1. All parts shown not sectioned are required by 2.14.1.10 to be NACE MRO175 material. All parts shown sectioned [shaded box] are not required to be NACE materials.
2. Applying NACE exposure guidelines allow the use of non-NACE bolting materials for external fasteners on the cylinder and internal fasteners within the distance pieces.
3. See Figure J-1 for reciprocating compressor nomenclature.

Figure P-1—Material Guidelines fo
With N



ꞩ for Compressor Components – Compliance
ı NACE MRO175

APPENDIX Q—INTERNATIONAL STANDARDS AND REFERENCED PUBLICATIONS

This appendix is a partial listing of publications referenced in 1.5 and corresponding International Standards.

The standards listed in 1.5 are the base documents. The corresponding international standards may be acceptable alternatives with the purchaser's approval.

Table Q-1—Corresponding International Standards

Note: The following table sets out corresponding International Standards that may be acceptable as alternatives with the purchaser's approval.

	Standard Origin					
Application	U.S.A.	International ISO	Germany DIN	Great Britian BSI	France AFNOR	Japan JIS
Shaft and housing fits, metric bearings	ANSI/ABMA Std 7	ISO 2982 ISO 2983	DIN 5425	5646 Part 1 5646 Part 2	NFE 22396	B0401 B1566
Load ratings and fatigue life—ball bearings	ANSI/ABMA Std 9	ISO 281	DIN 622	5512 Part 1	NF ISO 281	B1518 B1519
Load ratings and fatigue life—roller bearings	ANSI/ABMA Std 11	ISO 281-1				
Metric bearings boundary dimensions	ANSI/ABMA Std 20	ISO 5753		6107 Part 3	NF ISO 5753	B1512 B1513 B1514 B1520
Balance classification flexible couplings	ANSI/AGMA 9000-C90	ISO 1940/1 ISO 8821 ISO 5406	VDI 2060 DIN 740 Part A	6861 Part 1	NFE 90600	B0905 B0906
Bores and keyways flexible couplings	ANSI/AGMA 9002	ISO/R 773 ISO/R 774 ISO/R 775 ISO 286-1 ISO 286-2	DIN 740 DIN 6885 DIN 7190	3170 4235	NFE 02-E22175 NF ISO 286-1 NF ISO 286-2	B0903 B0904 B1301 B1303
Screw threads	ANSI/ASME B1.1	ISO 262 (Metric)		BS 3643 (Metric)	NFE 03-014	B0205 B0207 B0209 B0211
Cast iron pipe flanges	ANSI/ASME B 16.1	ISO 7005/2	DIN 2532 DIN 2533 DIN 2534 DIN 2535	4504	NFE 29206	
Steel and alloy pipe flanges	ANSI/ASME B 16.5	ISO 7005/1	DIN 2543 DIN 2544 DIN 2545 DIN 2546 DIN 2547 DIN 2548 DIN 2549 DIN 2550 DIN 2551	4504	NFE 29203/204	JPI-7S-15-1984
Forged fittings	ANSI/ASME B 16.11		DIN 910	BS 3799	NFE 29600	

Table Q-1—Corresponding International Standards (Continued)

Application	Standard Origin					
	U.S.A.	International ISO	Germany DIN	Great Britian BSI	France AFNOR	Japan JIS
Line conventions and lettering	ANSI/ASME Y 14.2M			308 Parts 2 & 3	NFE 04202/203	
Specification for line pipe	API SPEC 5L	ISO 6708 ISO 7268			NFE 29.001	
Packaged high-speed separable engine-driven reciprocating compressors	API SPEC 11P	ISO 13631				
Classification of electrical areas in petroleum refineries	API RP 500A	IED-Publ, 49		5345 Part 2	NF-S	RIIS-TR-79-1 RIIS-TR-85-1
General purpose steam turbines	API Std 611	ISO 10436	4312	132		
Special purpose steam turbines	API Std 612	ISO 10437				
Lubrication systems	API Std 614	ISO 10438	24425	4807		
Sound control		ISO 3744 ISO 3746 ISO 3740	DIN 45635P.1 DIN 45635P.2 DIN 45635P.8 DIN 45635P.24 DIN 45635P.40 DIN 45645	4196 Part 4 4196 Part 6 4196 Part 0	NFS 31027 NFS 31067 (For Sect. 2)	
Vibration position and bearing temperature monitoring	API Std 670	ISO 2372 ISO 3945	VDI 2056 VDI 2059	4675	NFE 90300 NFE 90301	
Special purpose couplings	API Std 671	ISO 10441				
General purpose gear units	API Std 677					
Shaft sealing systems for centrifugal and rotary pumps	API Std 682					
General purpose pipe threads	ANSI/ASME B1.20.1	ISO 288 PT.1		2779 (Seal on Gasket) 21 (Seal on Thread)	NFE 03.005	B0202 B0203
Chemical plant and petroleum refinery piping	ANSI/ASME B31.3			1600		B8270

Table Q-1—Corresponding International Standards (Continued)

Application	Standard Origin					
	U.S.A.	International ISO	Germany DIN	Great Britian BSI	France AFNOR	Japan JIS
Pressure casing design and construction:	ASME Boiler and Pressure Vessel Code:		AD-MERK-BLÄTTER			
Materials	Section II					
Non destructive examination	Section V		Sec. HP 5/3	4080 Parts I & II		G0801 Z2343 Z2344 Z3060
Rules for construction of pressure vessels	Section VIII Div. 1	ISO/R 831 ISO/TR 7468		5500	CODAP	B8270 G0565 Z2202 Z2242
Welding and brazing	Section IX		Sec. HP 2 SEW 110 8560/63	4870/1/2		Z3040 Z3801 Z3881 Z3891
Practice for rubber and rubber lattices	ASTM D 1418			6057	NFT 40002	
Guides for radiographic testing	ASTM E 94		5411/T. 1 & 2	2737 (For Castings)	UFA 04160 (For Castings)	G0581 Z3104 Z3106
Ref. photographs for magnetic indications	ASTM E 125		1650	4080 (For Acceptance Criteria)		G0565
Controlling quality of radiographic testing	ASTM E 142		54109	3971		G0581 Z3104 Z3106
Practice for magnetic particle examination	ASTM E 709		54130	6072	NFA 04193/A09590	G0565
Structural welding code—steel	ANSI/AWS D1.1			4780/1/2	NFP 22471	Code of Japan Welding Eng. Society
Standard industrial liquid lubricants—ISO viscosity class	ASTM D2422-68	ISO 3448		BS4231	NFT 60.141	K2001

Table Q-1—Corresponding International Standards (Continued)

Application	Standard Origin					
	U.S.A.	International ISO	Germany DIN	Great Britian BSI	France AFNOR	Japan JIS
Sulfide stress corrosion cracking resistant metallic materials for oil field equipment	NACE MR0175					
Steam turbines for mechanical drive service	NEMA SM 23					
National electric code	NFPA 70				NFC 02-205U	JEAC8001
Commercial blast cleaning	SSPC SP 6			7079		
Standard industrial liquid lubricants	ASTM D2422-68	ISO 3448		4231	NFT 60.141	
Zinc-coated welded and seamless black and hot-dipped steel pipe	ASTM A53					G3452/G3454
Carbon steel forgings for piping components	ASTM A105		1629 17155	1503	NFA 49.281	G3201 G3202 G4051
Seamless carbon steel pipe for high temperature service	ASTM A106		17175	3602	NFA 49.211	G3456
Black and hot-dipped zinc-coated (galvanized) welded and seamless steel pipe for ordinary uses	ASTM A120					G3442
Zinc coating (hot-dip) on iron and steel hardware	ASTM A153			1706		B3201
Carbon steel forgings for general purpose piping	ASTM A181		10083	1503	NFA 36.612	G3202
Forged or rolled alloy-steel pipe flanges, forged fittings, and valves and parts for high-temperature service	ASTM A182		17440 17175	1503	NFA 36.607	G3203 G3214
Alloy-steel and stainless steel bolting materials for high-temperature service	ASTM A193		17240/17440 17200/17245 17440	4882 1506	NFA 35558	G4107 G4303
Carbon and alloy-steel nuts for bolts for high-pressure and high-temperature service	ASTM A194		17440	4882 1506		G4051 G4303
Cupola malleable iron	ASTM A197					G5702

Table Q-1—Corresponding International Standards (Continued)

Application	Standard Origin					
	U.S.A.	International ISO	Germany DIN	Great Britian BSI	France AFNOR	Japan JIS
Carbon steel castings suitable for fusion welding for high-temperature service	ASTM A216		17245	1504	NFA 32055/32060	G5151
Martensitic stainless and alloy steel castings for pressure containing parts suitable for high-temperature service	ASTM A217		17445	1504	NFA 32055	G5121
Seamless and welded austenitic stainless steel tubing for general service	ASTM A269		17440	3605	NFA 49117	G3463
Stainless and heat-resisting steel bars and shapes	ASTM A276		17440	970	NFA 35544	G4303 G4317
Gray iron castings for pressure-containing parts	ASTM A278	ISO 185	1691 AD W 3/1 TRD 108	1452		G5501
Seamless and welded austenitic stainless steel and pipe	ASTM A312		17440	3605	NFA 49214/49219	G3459
Malleable iron flanges, pipe fittings, and valve parts for railroad, marine, and other heavy duty service at temperatures up to 650°F (345°C)	ASTM A338					G5702
Austenitic steel castings for high-temperature service	ASTM A351		17445 17465 SEW 410	1504	NFA 32055	G5121
Quenched and tempered alloy, hot-wrought or cold-finished steel bars	ASTM A434		EN 10083	BS EN10083-1	NFEN 10083-1	G4104 G4105
Austenitic gray iron castings	ASTM A436		1694	3468	NFA 32301	G5510
Austenitic ductile iron castings	ASTM A439		1694	3468	NFA 32301	G5510
Steel castings suitable for pressure service	ASTM A487		17245	1504	NFA 32055	G5121 G5151
Nickel and nickel alloy castings	ASTM A494					
Carbon steel plates for moderate and lower temperature pressure vessel service	ASTM A516			10028		G3106

Table Q-1—Corresponding International Standards (Continued)

Application	Standard Origin					
	U.S.A.	International ISO	Germany DIN	Great Britian BSI	France AFNOR	Japan JIS
Seamless carbon steel pipe for atmospheric and lower temperatures	ASTM A524					G3460
Hot-rolled and cold-finished age-hardening stainless and heat-resisting steel bars, wire, and shapes	ASTM A564					G4303 G4309
Special quality hot-wrought carbon steel bars	ASTM A576			970 Pt 3	NFA 35552	G4051
General application	ASTM A743		SEW 410			G5121
Iron-chromium-nickel and nickel base corrosion resistant castings for severe service	ASTM A744		17445	1504		
Precipitation hardening stainless steel castings	ASTM A747		SEW 410			G5121
White metal bearing alloys (known commercially as babbitt metal)	ASTM B23			3332		H5401
Aluminum-bronze castings	ASTM B148		1714	1400-AB2-C	NFA 53709	H5114
Nickel-copper alloy rod, bar, and wire	ASTM B164			3076-NA13		
Chromium-nickel-iron-molybdenum-copper-columbium stabilized alloy (Uns N08020) bar and wire	ASTM B473		17551			
Copper alloy sand castings for general applications	ASTM B584		17655	1400	NFA 53707-53709	H5101 H5102 H5111 H5112 H5115
Quality standard for steel castings for valves, flanges, and fittings and other piping components (visual method)	MSS-SP-55					

Notes: Materials for carbon steel piping, forged carbon steel fittings, valves, flanged components, and also stainless steel piping shall conform to the requirements of Table Q-2, Column 1. Corresponding International Standards may be acceptable as alternatives with the purchaser's approval.

(a) Schedule 80 for diameters from 1/2 NPS to 1–1/2 NPS.
Schedule 40 for diameters 2 NPS and larger.

(b) Schedule 40 for a diameter of 1/2 NPS to 1–1/2 NPS.
Schedule 10 for diameters of 2 NPS and larger.

(c) Acceptable tubing sizes are (see ISO 4200)
12.7 mm dia x 1.6 mm wall (1/2-inch diameter x 0.065-inch wall).
19 mm dia x 2.6 mm wall (3/4-inch diameter x 0.095-inch wall).
25 mm dia x 2.9 mm wall (1-inch diameter x 0.109-inch wall).
Tubing may be either 316 or 3

(d) Carbon steel slip-on flanges are permitted.

Table Q-2—International Piping Component Terms and Materials

	Standard Origin							
Component Terms	U.S.A. ASTM	UNS	International ISO	Germany DIN 17007	Germany DIN 17006	Great Britian BSI	France AFNOR	Japan JIS
Cooling water pipe	ASTM A53 Type F Sch 40 Galvanized to ASTM A153					BS 1706	TU26 CH18-12	
Lube oil pipe	ASTM A312 Type 316 Stainless	S31603	683-13-19	1.4404		BS 3605 Part 1 316.S.11	TU26 CN18-12 or TU26 CN 17-12	G3459 Gr SUS 316LTP
Tubing	ASTM A269 Seamless Type 316 stainless steel	S31600	2604 Gr TS61	1.4436		BS 3605 Part 1 316.S.33	TU26 CN18-12 or TU26 CN 17-12	G3459 GR SUS 316J1
Valve class	Class 800 Class 200 bronze		PN50 PN20					
Pipe fittings and unions (process fluid and steam)	Forged Class 3000							
Pipe fittings and unions (cooling water)	ASTM A338 and A197 Class 150 malleable iron galvanized to ASTM A153					BS 1706		
Pipe fittings and unions (lube oil)	Type 316L stainless	S31603	683-13-19	1.4404		BS 1503 316.S.11	Z6 CN18-09 or Z6 WD18-12-03	G3214 GR SUS 316L
Gaskets	Type 316 stainless steel spiral wound	S31600		1.4436	X.2 Cr Ni 19.11	BS 1449 Part 2 316.S.11	Z3 CN18-10 or Z3 CND17-12-02	SUS 316
Flange bolting	ASTM A193 Grade B7 ASTM A194 Grade 2H	G41300 G10350	2604-2-F31 683-1-C35e	1.7258	24Cr Mo5	1506-661	42Cr Mo4 2C 35	G4107 Cl SNB7 G4051 Cl S45C
Carbon steel piping	ASTM A53 Grade B or ASTM A106 Grade B or ASTM A524 or API Specification 5L, Grade A or B		2604	1.0254	St 37.0	BS 3602	TU 42C	G5456 Gr STPT 370/4110

Table Q-2—International Piping Component Terms and Materials (Continued)

Component Terms	Standard Origin							
	U.S.A. ASTM	UNS	International ISO	Germany DIN 17007	Germany DIN 17006	Great Britian BSI	France AFNOR	Japan JIS
Forged carbon steel fittings, valves, and flanged components	ASTM A105 or ASTM A181			1.0254	St 37.0	BS 1503	A48 CP	G4051 CI S25C
Stainless steel piping	ASTM A312 Type 316L stainless	S31603	683-13-19	1.4404	X3CrNiMo 17 13 2	BS 3605 Part 1 316.S.11	TU 26 CN18-12 or TU 26 CN17-12	G3459 Gr SUS 316LTP

Notes: Materials for carbon steel piping, forged carbon steel fittings, valves, flanged components, and also stainless steel piping shall conform to the minimum requirements of Table Q-2, Column 1. Corresponding International Standards may be acceptable as alternatives with the purchasers approval.

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