

Packaged Reciprocating Plant and Instrument Air Compressors for General Refinery Services

API STANDARD 680
FIRST EDITION, OCTOBER 1987

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



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Refining Department

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FOREWORD

This standard is based on the accumulated knowledge and experience of petroleum refiners and manufacturers of packaged reciprocating plant and instrument air compressors. The objective of this publication is to provide a purchase specification for double-acting reciprocating compressors of 600 brake horsepower and below for use in refinery services.

The primary purpose of API standards on mechanical equipment is to establish minimum mechanical 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 all modifications, deletions, and amplifications be made by supplementing this standard, rather than by rewriting or by incorporating sections thereof into another complete standard.

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

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 served as 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, 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 proposed rule by the U.S. Environmental Protection Agency proposing labeling requirements and phased banning of asbestos products, published at 51 *Federal Register* 3738-3759 (January 29, 1986).

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.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the Material Safety Data Sheet.

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Packaged Reciprocating Plant and Instrument Air Compressors for General Refinery Services

SECTION 1—GENERAL

1.1 Scope

This standard covers the minimum requirements for double-acting reciprocating compressors of 600 brake horse power (448 kilowatts) and below used in refinery services with lubricated or nonlubricated cylinders in utility air and/or instrument air service up to 125 pounds per square inch gage (8.6 bar). Driver, related lubricating systems, controls, instrumentation, intercooler, aftercooler, receiver, and other auxiliary equipment are covered in this standard. The compressor will generally be spared.

CAUTION: Compressors intended for instrument air service require dry cylinders to supply oil-free air. Compressors used in plant air service can be either of the dry-cylinder or lubricated-cylinder type construction. Because air/oil mixtures may ignite, the purchaser/user is cautioned of the need to carefully select the cylinder lubricant and consider all operating conditions. Temperature criteria are described in 2.3.

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

1.2 Alternative Designs

The vendor may offer alternative designs (see 5.1 for proposal requirements). 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

1.4.1 Terms used in this standard are defined in 1.4.1.1 through 1.4.1.18.

1.4.1.1 *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 the 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

1.4.1.2 *Inlet cubic feet per minute (ICFM)* refers to the flow rate determined at the conditions of pressure, temperature, compressibility, and moisture at the compressor inlet flange. [Inlet cubic feet per minute is identical to actual cubic feet per minute (ACFM)]

1.4.1.3 *Manufacturer's rated capacity* is the capacity used to size the compressor. The manufacturer's rated capacity is calculated by dividing the rated capacity (see 1.4.1.11) by 0.97. This result accommodates the acceptable normal manufacturing tolerance of ± 3 percent in capacity so that the rated capacity will never be less than the lower limit of the tolerance.

1.4.1.4 *Maximum allowable continuous rod loading* is the highest force that a manufacturer will permit for continuous operation on the compressor piston rod, the cross head assembly, the connecting rod, and the crankshaft.

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

1.4.1.6 *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). This includes operating in the unloaded condition.

1.4.1.7 *Maximum allowable working pressure* is the maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) (see 2.6.1.1).

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

1.4.1.9 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.

1.4.1.10 The *pressure casing* is the composite of all stationary pressure-containing parts of the unit, including all connections, nozzles, and other attached parts.

1.4.1.11 *Rated capacity* is the largest number of inlet cubic feet per minute required by the specified operating conditions.

1.4.1.12 *Rated discharge pressure* is the highest pressure required to meet the conditions the purchaser specifies for the intended service.

1.4.1.13 *Rated discharge temperature* is the predicted (not theoretical adiabatic) operating temperature resulting from the rated service conditions.

1.4.1.14 *Rated power* of the compressor is the maximum power the compressor plus any shaft-driven appurtenances require for any of the specified operating conditions. The rated power includes the effect of any equipment (such as pulsation suppression devices, piping, intercoolers, after-coolers, and separators) furnished by the compressor vendor. (Drive system losses are stated separately.)

1.4.1.15 *Rated speed* (in revolutions per minute) is the operating speed necessary to meet the rated service conditions.

1.4.1.16 *Standard cubic feet per minute (SCFM)* refers to capacity at a pressure of 14.7 pounds per square inch absolute (1.01 bar) and a temperature of 60 F (15.6 C).

1.4.1.17 *Standby service* refers to a normally idle or idling piece of equipment that is capable of immediate automatic or manual startup and continuous operation.

1.4.1.18 *Trip speed* (in revolutions per minute) is the speed at which the independent emergency overspeed device operates to shut down a prime mover. (For steam turbines and reciprocating engines, the trip speed shall be at least 110 percent of the maximum continuous speed. For gas turbines, the trip speed shall be at least 105 percent of the maximum continuous speed.)

1.4.2 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.

1.5 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 mutually agreed upon by the purchaser and the vendor.

AFBMA¹

Std 7 *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings*

AISI²

Standards, codes, and specifications of the American Iron and Steel Institute

ANSI³

- B1.1 *Unified Inch Screw Threads (UN and UNR Thread Form)*
- 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 Steel Fittings, Socket-Welding and Threaded*
- B16.42 *Ductile Iron Flanges and Flanged Fittings, Class 150 and 300*
- B31.3 *Chemical Plant and Petroleum Refinery Piping (ANSI/ASME B31.3)*
- S2.19 *Balance Quality of Rotating Rigid Bodies*
- Y14.2M *Line Conventions and Lettering*

API

- RP 500A *Classification of Areas for Electrical Installations in Petroleum Refineries*
- RP 520 *Recommended Practice for the Design and Installation of Pressure-Relieving Systems in Refineries, Part I—Design and Part II—Installation*
- Std 526 *Flanged Steel Safety Relief Valves*
- RP 550 *Manual on Installation of Refinery Instruments and Control Systems*
- Std 611 *General-Purpose Steam Turbines for Refinery Services*
- Std 613 *Special-Purpose Gear Units for Refinery Services*
- Std 615 *Sound Control for Mechanical Equipment for Refinery Services*
- Std 660 *Shell-and-Tube Heat Exchangers for General Refinery Services*
- Std 661 *Air-Cooled Heat Exchangers for General Refinery Services*
- Std 677 *General-Purpose Gear Units for Refinery Services (in preparation)*

ASME⁴

Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels, and Section IX, Welding and Brazing Qualifications

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

PTC 9 *Performance Test Code—Displacement Compressors, Vacuum Pumps and Blowers*

ASTM⁵

A 53 *Zinc-Coated Welded and Seamless Black and Hot-Dipped Steel Pipe*

A 106 *Seamless Carbon Steel Pipe for High-Temperature Service*

A 192 *Seamless Carbon Steel Boiler Tubes for High-Pressure Service*

A 247 *Evaluating the Microstructure of Graphite in Iron Castings*

A 269 *Seamless and Welded Austenitic Stainless Steel Tube for General Service*

A 278 *Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650°F (345°C)*

A 312 *Seamless and Welded Austenitic Stainless Steel Pipe*

A 358 *Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service*

A 395 *Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

A 515 *Carbon Steel Pressure Vessel Plates for Intermediate- and Higher-Temperature Service*

A 536 *Ductile Iron Castings*

E 125 *Reference Photographs for Magnetic Particle Indications on Ferrous Castings*

E 709 *Practice for Magnetic Particle Examination*

AWS⁶

D1.1 *Structural Welding Code—Steel*

NEMA⁷

MG 1 *Motors and Generators*

NFPA⁸

70 *National Electrical Code*, Article 500, "Hazardous Locations," and Article 501, "Class I Installation—Hazardous Locations"

OSHA⁹

Occupational Safety and Health Standards of the *Federal Register*

SAE¹⁰

Standards and specifications of the Society of Automotive Engineers

TEMA¹¹

Standards of the Tubular Exchanger Manufacturers Association

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

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. It is recognized that this is a design criterion.

2.1.2 The package vendor shall assume responsibility for the engineering coordination of the equipment and all auxiliary systems included in the scope of supply.

2.1.3 Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. Unless otherwise specified, the equipment furnished by the vendor shall conform to the requirements of API Standard 615 and to the maximum allowable sound pressure level specified by the purchaser.

¹Anti-Friction Bearing Manufacturers Association, 1234 Jefferson Davis Highway, Arlington, Virginia 22202.

²American Iron and Steel Institute, 1000 16th Street, N.W., Washington, D.C. 20036.

³American National Standards Institute, 1430 Broadway, New York, New York 10018.

⁴American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

⁵ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103.

⁶American Welding Society, 550 LeJeune Road, N.W. Miami, Florida 33135.

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

⁸National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269.

⁹Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C. 20210.

¹⁰Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.

¹¹Tubular Exchanger Manufacturers Association, 25 North Broadway, Terrytown, New York 10591.

2.1.4 Unless otherwise specified, cooling water systems shall be designed for the following conditions:

Velocity over heat exchange surfaces	5-8 ft/s	1.5-2.5 m/s
Maximum allowable working pressure	≥ 75 psig	≥ 5.2 bar (ga)
Test pressure	≥ 115 psig	≥ 7.9 bar (ga)
Maximum pressure drop	15 psi	1 bar
Maximum inlet temperature	90 F	32 C
Maximum outlet temperature	120 F	49 C
Maximum temperature rise	30 F	17 C
Minimum temperature rise	20 F	11 C
Fouling factor on water side	0.002 hr-ft ² ·°F/Btu	0.35 m ² ·K/kw

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

NOTE: The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflicting design. The criterion for velocity over heat 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.

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

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 Electrical components and installations shall be suitable for the area classification (class, group, and division) specified by the purchaser on the data sheets and shall meet the requirements of NFPA 70, Articles 500 and 501, 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, particularly packing and valves. Major parts such as cylinders and compressor frames should be shouldered or doweled to ensure accurate alignment on reassembly.

2.1.10 After installation, the combined performance of the package shall be the joint responsibility of the vendor and the purchaser. Units shall perform on the test stand and on their permanent foundation within the specified acceptance criteria.

2.1.11 The compressor power at the manufacturer's rated capacity shall not exceed the rated power by more than 3 percent.

● **2.1.12** Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at 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, and the vendor's representative shall observe a check of the piping performed by parting the flanges. The vendor's representative shall check alignment at the operating temperature and, when specified, shall be present during initial alignment check.

● **2.1.13** The purchaser will specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), as well as the weather and environmental conditions in which the equipment must operate (including maximum and minimum temperatures and unusual humidity or dust problems). The unit and its auxiliaries shall be suitable for operation in these specified conditions. For the purchaser's guidance, the vendor shall list in the proposal any special protection that the purchaser is required to supply (see 5.1, item l).

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

2.1.15 Bolting shall be furnished as specified in 2.1.15.1 through 2.1.15.4.

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

2.1.15.2 Studs are preferred to cap screws.

2.1.15.3 Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches. The vendor shall supply any required special tools and fixtures.

2.1.15.4 Socket-, slotted-nut-, or spanner-type bolting shall not be used unless specifically approved by purchaser.

2.1.16 Jackscrews, guide rods, and casing alignment dowels shall be provided to facilitate disassembly and reassembly of cylinder heads to cylinders.

2.1.17 Methods of lifting the assembled machine shall be specified by the vendor.

2.1.18 Provisions to ease removal of vertical piston and rod assemblies shall be included.

2.1.19 The machined finish of the mounting surfaces shall be 125 micro-inches (3.2 micrometers) arithmetic average roughness height (R_a) or better. Hold-down or foundation bolt holes shall be drilled perpendicular to the mounting surface or surfaces and spot faced to a diameter three times that of the hole.

2.1.20 Jacket cooling systems shall be designed to positively prevent leakage of air into the coolant or coolant into the air passages. The vendor shall state the method for achieving this in the proposal.

2.1.2.1 Compressor capacity shall at least equal the requirements of 1.4.1.3.

2.2 Allowable Speeds

- **2.2.1** 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 velocity [in feet (meters) per minute] and the maximum allowable rotating speed (in revolutions per minute) may be specified by the purchaser where experience indicates limits that should not be exceeded for a given service.

NOTE: Generally the piston velocities of compressors in nonlubricated services should be less than those in lubricated services.

- **2.2.2** To avoid excitation of torsional and acoustic resonances, reciprocating compressors should normally be specified for constant speed operation. When variable speed drivers are specified, 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 3.1).

2.3 Discharge Temperature

2.3.1 The rated discharge temperature resulting from any specified service conditions, including part-load operation, shall not exceed the following for each stage;

- a. 300 F for hydrocarbon oil lubricated cylinders.
- b. 360 F for nonlubricated cylinders.
- c. A temperature mutually agreed upon by the vendor and the purchaser for synthetic oil lubricated cylinders.

2.3.2 An alarm shall actuate when the discharge temperature of any cylinder exceeds the rated discharge temperature by 20 F (11 C).

2.3.3 An alarm shall actuate and the compressor shall shut

down when the discharge temperature of any cylinder exceeds the rated discharge temperature by 40 F (22 C).

2.4 Rod Loading

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

2.5 Dynamics

2.5.1 The compressor package vendor shall assume full responsibility for the performance of necessary lateral and torsional studies and the elimination of any lateral or torsional vibrations that may occur within the specified operating range in any specified loading step. The vendor shall state the speeds (from dead stop up to or down from trip speed or synchronous speed) at which all critical speeds occur.

2.5.2 Torsional natural frequencies of the driver-compressor system (including couplings and any gear unit) within 10 percent of any operating shaft speed or trip speed and within 5 percent of twice any operating shaft speed in the rotating system shall be avoided. For motor driven compressors, torsional natural frequency orders shall be separated from the first and second harmonics of the electrical frequency by the same range.

2.5.3 For geared units, involving either motor or steam turbine drivers, the vendor shall perform a torsional analysis of the compressor-gear-driver arrangement. This analysis shall verify that the limits of encroachment upon torsional natural frequencies as noted in 2.5.2 are met.

2.6 Compressor Cylinders

2.6.1 GENERAL

2.6.1.1 Maximum allowable working pressure shall exceed the rated discharge pressure by at least 10 percent or 10 pounds per square inch (0.7 bar), whichever is greater. The maximum allowable working pressure of the cylinder shall be at least equal to the specified relief valve setting.

2.6.1.2 Cylinders shall be spaced and arranged to permit access to all openings and components (including water jacket opening covers, distance piece covers, packing, valves, unloaders, or other controls mounted on the cylinder) without removing the cylinder, the cylinder head, or major piping.

2.6.1.3 Tandem two-stage construction is not acceptable.

2.6.1.4 If cylinder supports are required to avoid misalignment, they shall not be attached to the cylinder head. Rod run out shall not exceed 0.0005 inch per inch (0.012 millimeters per 25.4 millimeters) of stroke.

2.6.1.5 The walls of cylinders without liners shall be of a thickness sufficient to provide for a total of $\frac{1}{8}$ -inch (3.2-millimeter) diameter of overboring without encroaching upon either the maximum allowable working pressure or the maximum allowable rod load. Cylinder bore finish for lubricated services shall not exceed 63 micro-inches (1.6 micrometers) arithmetic average roughness height (R_a). Cylinder bores for nonlubricated services shall not exceed 32 micro-inches (0.81 micrometers) arithmetic average roughness height (R_a).

2.6.1.6 Cylinder heads, stuffing boxes for pressure packing, clearance pockets, and valve covers shall be fastened with studs. The cylinder lips supporting these components shall be so proportioned that overtightening studs up to 100 percent above the manufacturer's recommended torque will not cause lip failure. All stud holes shall be drilled no deeper than necessary to allow a maximum tap depth of one and one-half times the major diameter of the stud.

2.6.1.7 Cylinders shall have cooling provisions as required by conditions of service.

2.6.1.7.1 Air-cooled cylinders are acceptable for compressors rated at 75 horsepower (56 kilowatts) or less, provided that allowable discharge temperature limits as specified in 2.3 are not exceeded.

2.6.1.7.2 Compressors rated at powers greater than 75 horsepower (56 kilowatts) must be liquid cooled as follows:

a. For services where maximum expected discharge temperatures are less than 190 F (88 C) and the requirements of 2.6.1.7.2 item b have been satisfied, static-filled coolant systems may be supplied (see Plan A in Figure B-1 of Appendix B).

b. For services where expected maximum discharge temperatures are between 190 F (88 C) and 210 F (99 C), or where the adiabatic air temperature rise (difference between suction temperature and discharge temperature based on isentropic compression) is less than 150 F (66 C) and where cylinders will not be required to operate unloaded for extended periods of time, thermosyphon coolant systems may be supplied (see Plan B in Figure B-1).

c. For services where maximum expected discharge temperatures are above 210 F (99 C), where the adiabatic air temperature rise exceeds 150 F (66 C), or where cylinders will operate fully unloaded for extended periods of time,

forced liquid coolant circulation through cylinder jackets shall be provided (see Figure B-1, Plan C and cautionary note).

NOTE: For a high ambient temperature site condition of 110 F (43 C) or higher, thermosyphon or static-filled systems may not be suitable.

2.6.1.8 The cylinder cooling system provided shall be adequate to prevent condensation in the cylinder that may dilute or remove lubricant or cause knocking. The purchaser is cautioned regarding the following:

- a. Coolant inlet temperatures less than 10 F (6 C) higher than air inlet temperatures may cause air constituent condensation.
- b. Insufficient coolant flow and velocities may cause fouling of jackets and passages.
- c. Coolant exit temperature higher than 30 F (17 C) above air inlet temperature may result in a capacity reduction.

• **2.6.1.9** When specified, a self-contained, closed-jacket coolant system shall be furnished. It shall meet the following requirements (refer to Figure B-2 of Appendix B):

- a. The coolant supply to each cylinder jacket shall enter the jacket at a temperature at least 10 F (6 C) above air inlet temperature. A heating unit shall be provided for use during cold weather operation and prior to startup to bring the system up to temperature.
- b. The quantity of coolant circulated by each pump shall be regulated to maintain a coolant temperature rise across any individual cylinder, including the cylinder head, between 10 and 20 F (6 and 11 C).
- c. The system shall be pre-piped, factory skid mounted, and complete with the various pressure and temperature indicators, alarms, and other instrumentation as specified on the data sheets.

2.6.1.10 If nonlubricated or other special construction is specified, a complete description of piston, ring, and rod-packing designs (including materials of construction and cylinder bore finish) shall be included in the proposal.

2.6.1.11 Tapped holes in pressure parts shall be held to a minimum. To prevent leakage in pressure sections of castings, sufficient metal in addition to the allowance for corrosion shall be left around and below the bottom of drilled and tapped holes.

2.6.2 CYLINDER CONNECTIONS

2.6.2.1 Flanged or machined and studded inlet and outlet air connections are preferred. They shall be oriented as specified on the data sheets and suitable for the working pressure of the cylinder as defined in 1.4. Where flanged or machined and studded openings are impractical, threaded

openings are permissible in sizes 2-inch and 3-inch nominal pipe size, installed as described in 2.6.2.1.1 through 2.6.2.1.4.

2.6.2.1.1 A pipe nipple, preferably not more than 6 inches (152 millimeters) long, shall be screwed into the threaded opening.

2.6.2.1.2 Pipe nipples shall be Schedule 80.

2.6.2.1.3 The pipe nipple shall be provided with either a slip-on, welding-neck, or socket-weld flange.

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

2.6.2.2 Flanges shall conform to ANSI B16.1, B16.5, or B16.42 as applicable, except as noted in 2.6.2.2.1 and 2.6.2.2.2.

2.6.2.2.1 Flat-faced flanges with full raised face thicknesses are acceptable.

2.6.2.2.2 Flanges that are thicker or have a larger outside diameter than that required by ANSI are acceptable.

2.6.2.3 Machined and studded connections shall conform to ANSI B16.1, B16.5, or B16.42 for the facing and drilling requirements. Studs and nuts shall be furnished installed.

- **2.6.2.4** When specified, each cylinder shall have connections for attaching pressure transducers.

2.6.2.5 Openings for water and oil services may be threaded in sizes ½ inch through 2 inch nominal pipe size.

2.6.2.6 Openings for pipe sizes of 1¼, 2½, 3½, 5, 7, and 9 inches shall not be used.

2.6.2.7 Tapped openings not connected to piping shall be plugged with solid steel plugs furnished in accordance with ANSI B16.11. Plugs that may later require removal shall be of corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs are not permitted.

2.6.2.8 All purchaser's connections shall be accessible for disassembly without moving the machine.

2.7 Valves

2.7.1 Average inlet valve air velocity shall be computed as follows:

$$V = 288 D/A$$

Where:

V = average air velocity, in feet (meters) per minute.

D = cylinder displacement, in cubic feet (cubic meters) per minute.

A = product of the actual lift obtained in service and the valve-opening periphery; total for all inlet valves per cylinder in square inches (square meters).

NOTE: Valve lifts used in the above equation shall be shown on the data sheet.

- **2.7.2** Valve and unloader designs shall be suitable for operation as specified on the data sheets. Each individual step of unloading shall be provided with a visual indication of its position and its load (loaded or unloaded) condition. If valve unloading is required for startup, it shall be so stated in the proposal.

2.7.3 The valve design, including that for double-decked valves, shall be such that valve assemblies cannot be incorrectly assembled or interchanged nor shall it be possible to insert a valve assembly upside down.

2.7.4 Valve seats shall be removable. Valve seat-to-cylinder gaskets shall be the manufacturer's standard. Jacketed gaskets are preferred for the cover-to-cylinder joint.

2.7.5 The valve and cylinder designs shall be such that the valve cage or the assembly bolts (or both) cannot fall into the cylinder even if the valve assembly bolts break or unfasten.

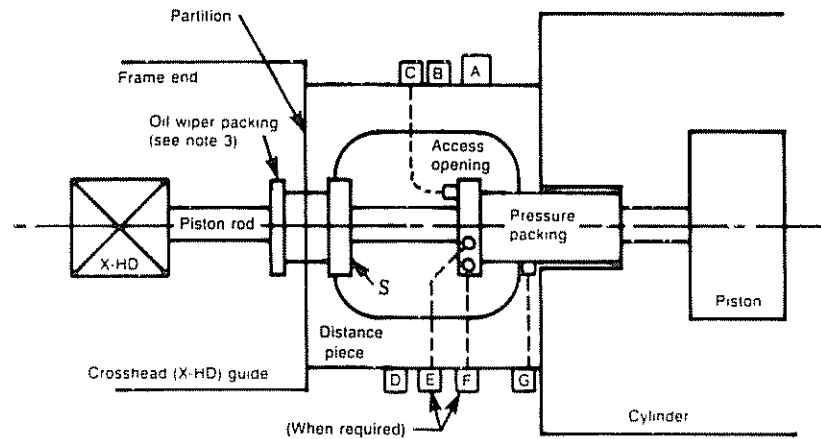
2.7.6 When furnished, the ends of the valve coil springs shall be square and ground to protect the plate against damage by the spring ends.

2.7.7 Valve hold-downs shall bear at no less than three points on the valve assembly. The bearing points shall be arranged as symmetrically as possible.

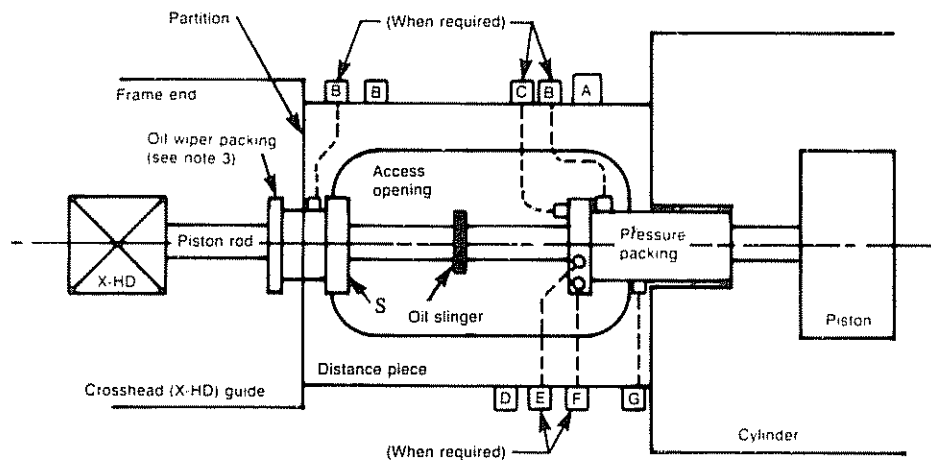
2.7.8 Metal valve disks or plates, when furnished, shall be suitable for installation with either side sealing and shall be lapped on both sides. Edges shall be suitably finished to remove stress risers.

2.8 Piston and Piston Rods

2.8.1 When pistons are removable from the rod, they shall be attached to the rod by a shoulder and lock nut design. The nuts on the end shall be positively locked in place. The rod shall be positively locked to the crosshead (when installed) to prevent rotation. The operating and maintenance



TYPE A
Short single-compartment distance piece
(may be integral with crosshead guide or distance piece)



TYPE B
Long single-compartment distance piece
(sufficient length for oil slinger travel)

Key

- A Vent (distance piece)
- B Purge, buffer, or pressure (packing or distance piece)
- C Lube (pressure packing)
- D Drain (distance piece)
- E Coolant out (pressure packing)
- F Coolant in (pressure packing)
- G Common vent and drain (pressure packing)
- S Seal or buffer packing (distance piece)

NOTES:

- 1 See 2.6 for connection sizes.
- 2 Orientation of distance pieces and packing flange/case connections may vary depending on individual distance piece and type of packing case used.
- 3 Oil wiper packing may be located in distance piece on either side of the partition from that shown and would be an integral assembly with the seal or buffer packing (S).

Figure 1—Distance Piece and Packing Arrangement

distance piece shall be equipped with oil wiper rings. For lubricated service, the crank end of the distance piece shall be equipped with two oil wiper rings installed for wiping in both directions.

2.11 Stuffing Boxes and Packing

2.11.1 If a particular packing is not specified by the purchaser on the data sheets, the manufacturer shall recommend a packing arrangement for the specified service.

2.11.2 Glands shall be bolted to the cylinder head or to the cylinder.

2.11.3 In both lubricated and nonlubricated service, adequate radial clearance shall be provided between the piston rod surface and the crank-end cylinder head bore, the compressor cylinder packing case, and the gland bore to eliminate possible scoring when maximum wear of the piston wear band occurs.

2.11.4 All oil wiper and seal rings shall be segmented and have garter springs.

2.12 Compressor Frame Lubrication

2.12.1 The frame lubrication system shall be a pressure system; however, splash systems may be used to lubricate crankshaft antifriction bearings on compressors of 350 horsepower (261 kilowatts) or less. Crankcase oil temperature shall not exceed 160 F (71 C) for pressurized oil systems and 180 F (82 C) for splash systems.

2.12.2 Pressure lubrication systems shall consist of a shaft-driven oil pump with a suction strainer, a supply and return system, an oil cooler (when required), a full-flow filter, and other necessary instruments. Unless otherwise specified, the compressor crankcase shall also function as the oil reservoir.

2.12.3 All oil-containing pressure components, including the auxiliary pump (if any), shall be steel, except that crankshaft-driven lube oil pumps and other components internal to the compressor frame may have cast iron or nodular iron construction.

● **2.12.4** When specified, a separate, full-capacity, full-pressure auxiliary pump with an automatic start at low lubrication oil pressure shall be provided by the package vendor.

2.12.5 Both main and auxiliary pumps shall be provided with pressure relief valves piped back to the crankcase reservoir. Nonintegral relief valves are preferred.

● **2.12.6** An oil cooler shall be provided if required to maintain lube oil supply temperature at or below 130 F (54 C). The cooler shall be a water-cooled, shell-and-tube type, or it shall be a suitable air-cooled type, as specified. Shell-and-tube coolers shall have water on the tube side. A removable bundle design is required for coolers having more than 5 square feet (0.46 square meter) of surface, unless otherwise specified by the purchaser. 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 $\frac{3}{8}$ inch (16 millimeters), and the tube wall shall not have a thickness of less than 18 Birmingham wire gage (BWG) [0.049 inches (91.25 millimeters)]. U-bend tubes are not permitted. The vendor shall state the lubricating oil pressure at the cooler outlet so that the purchaser may provide water at a lower pressure, if desired, to prevent contamination of the lubricating oil in case of cooler failure. Unless otherwise specified, shells, channels, and covers for the coolers shall be steel; tube sheets shall be naval brass; and tubes shall be inhibited admiralty. Coolers shall be equipped with vent and drain connections on their oil and water sides. The vendor shall include complete details of any proposed air-cooled cooler in the proposal. Internal oil coolers are not acceptable. When specified, lube oil temperature should be thermostatically controlled.

● **2.12.7** The manufacturer's standard full-flow filter shall be supplied with filtration of 25 microns nominal or finer for babbitted bearings and 10 microns nominal or finer for aluminum or microbabbitted bearings. The filter shall be located downstream of the cooler. Filter cases and heads shall be suitable for operation at a pressure not less than the discharge pressure of the oil pump. The filter shall not be equipped with an internal relief valve or bypass. Filter cartridge materials shall be corrosion resistant. For all replaceable cartridge filters, the clean pressure drop shall not exceed 5 pounds per square inch (0.34 bar) at design temperature and flow. The cartridge collapse differential pressure drop shall not be less than 70 pounds per square inch (4.8 bar). When specified, dual filters shall be supplied complete with a separate or integral continuous flow transfer valve. The filter or filters shall be equipped with vent and clean- and dirty-side drain connections. A dual filter system shall be designed to permit cartridge replacement and repressuring during operation.

● **2.12.8** When specified, a removable steam-heating element inserted in the crankcase (oil reservoir) or a thermostatically controlled electrical immersion heater with sheath of Series 300 stainless steel shall be provided for heating the charge capacity of oil before startup in cold weather. The heating device shall have sufficient capacity to heat the oil in the crankcase from the specified minimum

site ambient temperature to 80 F (27 C) within 12 hours. If an electrical immersion heater is used, it shall have a maximum watt density of 15 watts per square inch (2.3 watts per square centimeter).

2.12.9 The crankcase (oil reservoir) shall be supplied with the following characteristics and appendages:

- a. The capacity to settle moisture and foreign matter adequately, to avoid frequent refilling, and to provide adequate allowance for system run down.
- b. Fill connections, level indicators, and breathers suitable for outdoor use.
- c. Sloped bottoms and connections to complete drainage.
- d. Cleanout openings as large as is practicable.
- e. An interior that has been descaled and protected from rust by the manufacturer's standard procedure, subject to the purchaser's approval. (Permanent surface coatings shall not be applied without the purchaser's specific approval.)

2.13 Cylinder and Packing Lubrication

2.13.1 Lubrication to compressor cylinders shall be provided by forced-feed mechanical lubricators, as specified, either single-plunger-per-feed or divider-block types separate from the frame lubrication pump and complete with necessary tubing or piping (see 3.7.3). Single-plunger-per feed lubricators shall have a sight flow indicator for each lubrication point. A lubrication point (or points) shall be provided on the compressor cylinder bore. A lubrication point shall be provided for rod packing except in certain air compressors where the packing is lubricated from the cylinder. A check valve shall be provided at each lubrication point. Mechanical lubricators shall have provision for a prelubrication operation prior to compressor startup. Reservoir capacity shall be adequate for 30 hours. All controls on the cylinder and packing lubrication system shall be adjustable while the compressor is operating. If an electrical immersion heater is used, it shall have a maximum watt density of 15 watts per square inch (2.3 watts per square centimeter).

● **2.13.2** When specified, a heating device for the reservoir oil shall be provided.

● **2.13.3** The purchaser will specify when compressor cylinders will be lubricated by synthetic lubricants. The lubricant specifications shall be entered on the data sheets by the purchaser unless the vendor's recommendation is desired. All gaskets, seals, unloader diaphragms, packing, lubricator parts, and other parts coming in contact with the synthetic lubricant shall be of compatible materials agreed upon by the compressor manufacturer and the lubricant manufacturer. Synthetic cylinder lubricant in the cylinders may contaminate

the crankcase oil; therefore, crankcase interior surfaces should be left unpainted. If interior surfaces must be painted, a synthetic-lubricant-resistant coating recommended by the lubricant manufacturer shall be used.

2.14 Materials

2.14.1 GENERAL

2.14.1.1 Materials for compressor parts shall be in accordance with those listed in Appendix C, except that superior or alternative materials recommended by the vendor shall be listed on the data sheets. See 3.7.1 for auxiliary piping material requirements.

2.14.1.2 Materials shall be identified in the proposal with their applicable ASTM, AISI, ASME, or SAE numbers, including the material grade (see Appendix C). When no such designation is available, the vendor's material specification, giving physical properties, chemical composition, and test requirements, shall be included in the proposal (see 5.1, item k and 5.2.4.3).

2.14.1.3 The vendor shall specify the ASTM optional tests and inspection procedures necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The purchaser should consider specifying additional tests and inspections, especially for material in critical service (see 5.1, item j).

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

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

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

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

2.14.1.8 Materials, casting factors, and the quality of any welding shall be equal to those required by Section VIII, Division 1, of the ASME Code. The manufacturer's data report forms, as specified in the code, are not required (see 2.14.4.2).

2.14.2 CASTINGS

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

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

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

2.14.2.4 For compressors below 150 horsepower (112 kilowatts), crankshafts made of ASTM A 536 ductile iron Grade 100-70-03 are acceptable. Crankshafts of ASTM A 278 gray cast iron are not acceptable. All offerings for ductile iron crankshafts (see 2.10) shall be reviewed with the purchaser for additional nondestructive testing requirements not required by the ASTM specification.

2.14.2.5 Ferrous castings shall not be repaired by welding, peening, plugging, or burning in except as specified in 2.14.2.5.1 and 2.14.2.5.2.

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

2.14.2.5.2 Cast gray iron or ductile iron may be repaired by plugging within the limits specified in ASTM A 278 or A 395, respectively. The drilled holes for a plug shall be carefully examined, using dye penetrant, to ensure the removal of all defective material. All necessary repairs not covered by ASTM specifications shall be subject to the purchaser's approval. Weld repairs are not permitted.

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

● **2.14.2.7** If specified, cylinders and cylinder heads of ductile iron shall be produced in accordance with ASTM A 395. The production of the castings shall also conform to the conditions specified in 2.14.2.7.1 through 2.14.2.7.5.

2.14.2.7.1 A minimum of one set of Charpy V-notch impact specimens at one third of the thickness of the test block 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 10 foot-pounds (13.6 joules) at room temperature.

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

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

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

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

2.14.2.8 Impregnation of pressure-containing castings shall require prior purchaser approval.

NOTE: Appendix D describes some repair procedures that may be considered for gray or ductile iron castings. These techniques should only be applied after a thorough mutual evaluation by the purchaser and the vendor.

2.14.3 FORGINGS

Unless otherwise agreed upon by the purchaser and the vendor, forging material shall be selected from those listed in Appendix C.

2.14.4 WELDING

2.14.4.1 Welding of pipes and pressure-containing parts, as well as any dissimilar-metal welds or weld repairs, shall be performed by operators and procedures qualified in accordance with Section IX of the ASME Code.

2.14.4.2 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 2.14.1.8).

2.14.4.3 Inspection of repair welds shall be performed in accordance with 2.14.6.3.

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

● 2.14.5 LOW TEMPERATURE

For operating temperatures below $-20\text{ F } (-29\text{ C})$ and when specified for other low ambient temperature, steels shall have, at the lowest specified temperature, an impact strength sufficient to qualify under the minimum Charpy V-notch impact energy requirements of Section VIII, Division 1, UG-84, of the ASME Code. For materials and thicknesses not covered by the code, the purchaser shall specify the requirements on the data sheets.

2.14.6 MATERIAL INSPECTION

● **2.14.6.1** When radiography, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, radiography shall be in accordance with Section VIII, UW-52, of the ASME Code; ultrasonic examination shall be in accordance with Section VIII, Division 1, Appendix 12, of the ASME Code; magnetic particle examination shall be in accordance with Section VIII, Division 1, Appendix 6, and liquid penetrant examination shall be in accordance with Section VIII, Division 1, Appendix 8, of the ASME Code.

2.14.6.2 For crankshafts, frames, and cylinders and any other major components, fully identified records of all heat treatment and radiography, whether performed in the normal course of manufacture or as part of a repair procedure, shall be kept available for 5 years for review by the purchaser.

2.14.6.3 When magnetic particle examination as described in ASTM E 709 is required, acceptability of defects 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 in the following table:

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

Regardless of these generalized limits, it shall be the vendor's responsibility to review the design limits of all castings in the event that more stringent requirements are specified. Defects that exceed the limits imposed above shall be removed to meet the quality standards cited above, as determined by additional magnetic particle inspection, before repair welding (see 2.14.4.3).

2.15 Nameplates and Rotation Arrows

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

2.15.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment. Nameplates and rotation arrows (if attached) shall be of Series 300 stainless steel or of nickel-copper alloy (Monel or its equivalent). Attachment pins shall be of the same material.

2.15.3 The purchaser's item number, the vendor's name, the machine's serial number, the compressor size and type, the maximum allowable design limits and rating data (including pressures, temperatures, speeds, and power), cylinder rated pressure(s), the maximum allowable working pressures and temperatures, hydrostatic test pressures, the total end clearance, and the cold clearance setting for each end shall appear on each compressor nameplate.

SECTION 3—ACCESSORIES

3.1 Drivers

3.1.1 The type of driver shall be specified by the purchaser. The driver shall be sized to meet the manufacturer's rated capacity (see 1.4.1.3), including external gear and/or coupling losses, and shall be in accordance with applicable specifications, as stated in the inquiry and the order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified by the purchaser.

● **3.1.2** Anticipated inlet variations that may affect the sizing of the driver (such as changes in temperature and special plant startup conditions) will be specified by the purchaser.

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

3.1.4 For motor-driven units, the motor nameplate rating (exclusive of the service factor) shall be at least 110 percent of the manufacturer's rated capacity (including gear and coupling losses) for any of the specified operating conditions.

3.1.5 The purchaser will specify the type of motor and its characteristics, including the following:

- a. Electrical characteristics.
- b. Starting conditions (including the expected voltage drop on starting).
- c. The type of enclosure.
- d. The sound pressure level.
- e. The area classification, based on API Recommended Practice 500A.
- f. The type of insulation.
- g. The required service factor.
- h. The ambient temperature and elevation above sea level.
- i. Transmission losses.

NOTE: If required, temperature detectors, vibration sensors, space heaters, and other accessories will be specified.

- **3.1.6** The motor's starting-torque requirements shall be met at a reduced voltage specified by the purchaser, and the motor shall accelerate to full speed within a period of time agreed upon by the purchaser and the vendor. Unless otherwise specified, the starting voltage will be 80 percent of the normal voltage, and the time required to accelerate to full speed will be less than 15 seconds.

3.1.7 Motors for auxiliary equipment shall be suitable for the area classification specified and shall be in accordance with Article 500 of NFPA 70.

3.1.8 Steam turbine drivers shall conform to API Standard 611. Steam turbine drivers shall be sized to continuously deliver 110 percent of the manufacturer's rated capacity while operating at a corresponding speed with the specified steam conditions.

3.1.9 Speed irregularity of belt driven units shall not exceed 2 percent of nominal compressor speed.

3.1.10 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 MG 1, Paragraph 21.84) for all specified loading conditions including unloaded suction pressures. For induction motor-compressor installations, motor current variations shall not exceed 40 percent of the full load current. The purchaser shall 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 when subjected to 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 2.2.2.

- **3.1.11** When the motor is supplied by the purchaser, the compressor vendor shall furnish the purchaser with the following:

- a. Compressor torque effort diagram and/or inertia to satisfy flywheel requirements of the compressor for all specified operating conditions.
- b. Starting torque requirements.
- c. Mounting details, coupling details, or both.

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

3.2 Couplings and Guards

3.2.1 GENERAL

3.2.1.1 Flexible couplings and guards between drivers and driven equipment shall be supplied by the manufacturer of the driven equipment, unless otherwise specified on the data sheets.

3.2.1.2 The coupling make, type, and mounting arrangement shall be agreed upon by the driver and driven equipment vendors and by the purchaser. A spacer coupling shall be used, unless otherwise specified.

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

3.2.1.4 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.

3.2.1.5 Each coupling shall have a coupling guard that sufficiently encloses the coupling and shafts to prevent any access to the danger zone by personnel during operation of the equipment train.

3.2.1.6 The guard shall be readily removable for inspection and maintenance of the coupling without disturbing the coupled machines.

3.2.1.7 The guard shall comply with OSHA Standard 1910.219.

- **3.2.1.8** When specified by the purchaser, the guard shall be fabricated from spark-resistant materials. A description of the materials of construction shall be submitted to the purchaser for approval.

3.2.1.9 Guards that are fastened to the equipment foundation or baseplate shall be removable in one piece.

3.2.1.10 Base-mounted guards shall preferably be fabricated from solid metal sheet or plate with no openings. Guards fabricated from expanded metal or perforated plate are acceptable provided that the size of the opening is small enough to prevent entry by objects $\frac{3}{8}$ inch (9.5 millimeters) or larger in diameter. Guards fabricated from woven wire are unacceptable.

3.2.2 GUARDS FOR FLEXIBLE-DISK HIGH-SPEED COUPLINGS

- **3.2.2.1** When specified by the purchaser for turbine-gear box drivers, guards shall be designed to be essentially airtight at the radial and axial flanged joints and at the slip joint, if any. Guard design shall allow for potential heating caused by windage.

- **3.2.2.2** When specified, a flanged oil-drain connection [1 inch (2.5 centimeters) nominal or larger] shall be provided to handle any oil carry over into the guard from the coupled equipment.

3.3 Reduction Gears

The gear unit design shall conform to API Standard 613 or 677, as specified.

3.4 Belt Drives

- **3.4.1** Belt drives shall be limited to compressors of 200 brake horsepower (149 kilowatts) or less and shall be banded multi-vee belts, unless otherwise specified. If more than one banded multi-vee belt is required, the vendor shall furnish matched belt lengths. All belt drives shall be oil resistant (with a neoprene or equivalent material cover). The drive service factor shall not be less than 1.75 times the driver nameplate power rating. When service in a hazardous area is specified, belt drivers of the static-conducting type shall be provided (see 3.2 for belt drive guards).

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.

3.4.3 The compressor manufacturer shall inform the driver manufacturer when the driver is to be used to belt-drive a compressor. The driver manufacturer shall be provided with the radial load and vibratory torque conditions associated with reciprocating compressors and shall account for this in the driver selection.

3.4.4 For belt drives, the practices described in 3.4.4.1 through 3.4.4.7 shall be incorporated.

3.4.4.1 Sheave center distance shall be no less than 1.5 times the large sheave diameter.

3.4.4.2 The belt wrap (contact) angle on the smaller sheave shall be no less than 140 degrees.

3.4.4.3 The shaft length for fitting the sheave hub shall be equal to or greater than the sheave hub width.

3.4.4.4 Shaft key fitting lengths for sheave mounting shall be no less than the sheave bore length.

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

3.4.4.6 To reduce bearing moment loading (belt tension), a minimum sheave overhang distance for the sheave-to-shaft fitting shall be provided.

3.4.4.7 Sheaves shall be balanced to ANSI S2.19 Grade 6.3.

3.5 Baseplates

- **3.5.1** When a baseplate is specified, the data sheets will show the extent. 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 40 feet (12 meters) or a nominal width of more than 12 feet (3.6 meters) may have to be fabricated in multiple sections because of shipping restrictions.

- **3.5.2** 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.

- **3.5.3** 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 mounting pads on the bottom of the baseplate shall be in one plane to permit use of a single-level foundation. When specified, subsoleplates shall be provided by the vendor.

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

- **3.5.5** When specified, the equipment feet and baseplates shall be equipped with vertical jackscrews to ease shim installation.

3.5.6 If mounted direct-driven rotating equipment weighs more than 1000 pounds (454 kilograms), the mounting plates shall be furnished with horizontal jackscrews the same size or larger than the vertical jackscrews.

3.5.7 Machinery supports shall be designed to limit a change of alignment caused by the worst combination of pressure, torque, or allowable piping stress to 0.005 inches (127 micrometers) at the coupling flange.

- **3.5.8** When epoxy grout is specified on the data sheets, the vendor shall precoat all the grouting surfaces of the mounting plates with a catalyzed epoxy primer applied to degreased white metal. The epoxy primer shall be compatible with the epoxy grout. The vendor shall submit to the purchaser instructions for field preparation of the epoxy primer.

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

3.5.10 Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates intended for installation on concrete shall be supplied with leveling screws. Mounting plates that are to be grouted shall have 2-inch-radius (50-millimeter-radius) corners (in the plan view).

3.5.11 Anchor bolts will be furnished by the purchaser.

3.6 Controls and Instrumentation

3.6.1 GENERAL

- **3.6.1.1** Compressor control systems may be pneumatic, electrical, or electronic and may be operated either manually or automatically. The purchaser will specify the control signal, the type of control system (manual or automatic), the control range, and the equipment to be furnished by the vendor.

3.6.1.2 Controls and instrumentation shall conform where practical, with API Recommended Practice 550, Part I.

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

3.6.1.4 When more than one wiring point is required on the package for instrumentation control, wiring to each switch or instrument shall be provided from a single terminal box mounted on the package. Wiring shall be installed in conduit.

- **3.6.1.5** When specified, lead-lag or base-loaded control methods to sequence multiple compressor systems shall be provided.

- **3.6.1.6** When specified, all instruments and controls other than shutdown-sensing devices shall be installed with sufficient valving to permit removal of instruments and controls while the system is in operation.

3.6.2 CAPACITY CONTROL SYSTEMS

- **3.6.2.1** Capacity control shall normally be obtained by suction valve unloading, clearance pockets, a combination of both pockets and unloaders, or other control methods mutually agreed upon by the purchaser and the vendor. Control operation shall be automatic and/or manual as specified on the data sheets. Five-step unloading shall provide capacities of 100, 75, 50, 25, and 0 percent; three-step unloading shall provide capacities of 100, 50, and 0 percent; and two-step unloading shall provide capacities of 100 and 0 percent.

NOTE: Suction and clearance valve unloading configurations normally available consist of the following: two-step, less than 100 brake horsepower (75 kilowatts); three-step, 100-250 brake horsepower (75-187 kilowatts); five-step, optional for over 250 brake horsepower (187 kilowatts).

3.6.2.2 For turbine and engine drivers, actuation of the control signal or failure of the signal or actuator shall not prevent the governor from limiting the speed to the maximum permissible speed.

3.6.2.3 When furnished, clearance pockets shall be of the two-position type (either open or closed).

- **3.6.2.4** The unloading arrangement used for startup shall be stated on the data sheets or shall be mutually agreed upon by the purchaser and the vendor.

- **3.6.2.5** Cylinder unloading may be accomplished by the use of valve depressors, the opening of clearance pockets,

an internal bypass, or other methods mutually agreed upon by the purchaser and the vendor. Valve lifters shall not be used. When valve depressors are specified, all inlet valves of the cylinder ends involved shall be provided with unloaders.

3.6.3 CONTROL STATION

- **3.6.3.1** When specified, a control station shall be provided that includes a gage board and a NEMA 4 enclosure. All electrical devices shall be housed in the NEMA 4 enclosure, and other instrumentation and controls shall be mounted on the gage board. Motor-driven compressors shall be started from the station. The station shall be mounted on the compressor baseplate and protected from vibration. Refer to the data sheets for area classification and enclosures required. Certain area classifications may require purging or alternative types of enclosures. When required, purge connections shall be provided with a rotameter-type flow indicator. The instruments on the panel shall be clearly readable by the operator.
- **3.6.3.2** When specified, a weather hood for outdoor installations, including an overhead light, shall be provided over the control station.

3.6.3.3 The station shall include the following:

- a. Pressure gages.
 - (1). Lube oil.
 - (2). Discharge air (each stage).
 - b. All required start/stop buttons.
 - c. Running light(s).
 - d. One alarm and one shutdown indicating light for each of the following:
 - (1). Low lube oil pressure (if applicable).
 - (2). High discharge air temperature (each stage).
 - (3). High cooling water discharge temperature (each stage).
 - e. Lamp test push button.
 - f. Capacity control load indicators.
 - g. Load-unload selector switch.
 - h. Horn.
- In addition to the mandatory shutdowns listed above, additional alarms and shutdowns may be specified on the data sheets. When this is done, switches, control devices, indicating lights, and/or annunciator display units shall be furnished and mounted by the vendor, as specified by the purchaser.

3.6.3.4 The control station shall be completely piped and wired, requiring only connection to the purchaser's exter-

nal piping and wiring circuits. Wiring shall be installed in conduit. All leads, posts on terminal strips, switches, and instruments shall be tagged for proper identification.

3.6.3.5 No terminal blocks shall be located in wireways. The terminals shall be of the straight-through-compression type with shrouded screws (dead front) and center tapping for test purposes. Terminal block connections shall be single level (not tiered). The NEMA enclosure shall contain two ¼ by 1 inch minimum (6 by 25 millimeters) bare soft copper, solid bar grounding buses. One shall be used for a signal ground, the other as an equipment ground bus. The instrument case shall not be grounded through the steel of the enclosure.

3.6.4 INSTRUMENTATION

3.6.4.1 Locally Mounted Instrumentation

Locally mounted instrumentation shall be provided as follows:

- a. Discharge air temperature at each stage.
- b. Cooling jacket water discharge temperature.
- c. Reservoir oil level indicator.
- d. Oil cooler inlet and outlet oil temperature.

● 3.6.4.2 Tachometers

A tachometer shall be provided for engine-driven units and, when specified, for other variable-speed units. The type of tachometer (electrical, mechanical, vibrating reed, and so forth) will be specified by the purchaser on the data sheets. Mechanical tachometers shall be equipped with a disengaging clutch. Unless otherwise specified, the minimum tachometer range shall be from 0 to 125 percent of the maximum continuous speed.

3.6.4.3 Temperature Measurement Thermometers and Temperature Gages

3.6.4.3.1 Dial-type temperature gages shall be heavy duty and corrosion resistant. They shall be at least 5 inches (127 millimeters) in diameter and bimetallic or mercury filled. Black printing on a white background is standard for gages.

3.6.4.3.2 Metal-case, glass-front, stem-type bimetallic mercury thermometers shall be furnished.

3.6.4.3.3 The sensing element of thermometers and temperature gages shall be in the flowing fluid.

3.6.4.4 Thermowells

Thermometers and temperature gages shall be furnished with Series 300 stainless steel solid-bar thermowells at least