

Specification for Packaged Reciprocating Compressors for Oil and Gas Production Services

API SPECIFICATION 11P (SPEC 11P)
SECOND EDITION, NOVEMBER 1, 1989

American Petroleum Institute
1220 L Street, Northwest
Washington, DC 20005



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Note:

This edition supersedes the first edition dated February 1975. It includes changes adopted by special letter ballot dated January 5, 1988.

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FOREWORD

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f. The purpose of API Standards on Production Equipment is to establish minimum requirements relating primarily to mechanical considerations. This limitation in scope is one of charter as opposed to interest or 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, packager and purchaser during these steps. Alternative approaches which may result in improved energy utilization should be thoroughly investigated and brought forth. This is especially true of new equipment proposals, as the evaluation of purchase options will be increasingly based on the total life costs versus low initial cost. Equipment manufacturers and packagers, in particular, are encouraged to suggest alternatives to those specified when these approaches achieve improved energy effectiveness and reduced total life costs without sacrifice of safety, quality, or reliability.

This standard is based upon the accumulated knowledge and experience of manufacturers, packagers and purchasers of reciprocating compressors. The objective of this publication is to provide a purchase specification to facilitate the manufacture and procurement of reciprocating compressor packages for oil and gas production services.

This standard requires the purchaser to specify certain details and features. A bullet (•) in the margin indicates that a decision by the purchaser is required. These decisions should be indicated clearly on the data sheets. 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 Chairman, Committee on Standardization of Production Equipment, American Petroleum Institute, Production Department, 2535 One Main Place, Dallas TX 75202-3904.

g. This Standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

h. The current editions of the following standards, codes, and specifications 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 packager.

RELATED CODES AND STANDARDS ARE AS FOLLOWS:

AFBMA:	Anti-Friction Bearing Manufacturers Association, 1235 Jefferson Davis Highway, Arlington, Virginia 22202.
AFBMA STD 11:	Load Ratings and Fatigue Life for Roller Bearings
ANSI:	American National Standards Institute, 1430 Broadway, New York, New York 10018.
ANSI B1.1:	Unified Screw Threads.
ANSI B1.20.1:	Pipe Threads, General Purpose (Inch).
ANSI B16.1:	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800.
ANSI B16.5:	Pipe Flanges and Flanged Fittings, Steel Nickel Alloy and Other Special Alloys.



ANSI B16.42:	Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300.	ASTM A-216:	Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service.
API:	American Petroleum Institute, Production Department, 211 N. Ervay, Suite 1700, Dallas, Texas 75201.	ASTM A-269:	Seamless and Welded Austenitic Stainless Steel Tubing for General Service.
API STD 1B:	Specification for Oil-Field V-Belting.	ASTM A-278:	Gray Iron Castings for Pressure-Containing Parts for Temperatures Up To 650 Deg. F.
API RP 14F:	Recommended Practice for Design and Installation of Electrical Systems for Offshore Production Platforms.	ASTM A-307:	Carbon Steel Externally Threaded Standard Fasteners.
API RP 500B:	Recommended Practice for Classification of Locations for Electrical Installations at Drilling Rigs and Production Facilities on Land and on Marine Fixed and Mobile Platforms.	ASTM A-312:	Seamless and Welded Austenitic Stainless Steel Pipe.
API RP 520:	Recommended Practice for the Design and Installation of Pressure-Relieving Systems in Refineries, Part I — Design and Part II — Installation.	ASTM A-320:	Alloy-Steel Bolting Materials for Low-Temperature Service.
ASME:	American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.	ASTM A-358:	Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service.
ANSI/ASME B31.3:	Chemical Plant and Petroleum Refinery Piping, A Section of the ASME Code for Pressure Piping.	ASTM A-395:	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures.
ASME SEC II:	Boiler and Pressure Vessel Code, Material Specifications.	ASTM A-487:	Steel Castings Suitable for Pressure Service.
ASME SEC VIII:	Boiler and Pressure Vessel Code, Rules for Construction of Pressure Vessels.	ASTM A-508:	Ultrasonic Examination of Large Forged Crankshafts.
ASME SEC IX:	Boiler and Pressure Vessel Code, Welding and Brazing Qualifications.	ASTM A-536:	Ductile Iron Castings.
ASTM:	American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.	ASTM A-668:	Steel Forgings, Carbon and Alloy, for General Industrial Use.
ASTM A-53:	Material Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.	ASTM A-703:	Steel Castings, General Requirements for Pressure Containing Parts.
ASTM A-106:	Seamless Carbon Steel Pipe for High-Temperature Service.	ASTM A-781:	Castings, Steel and Alloy, Common Requirements for General Industrial Use.
ASTM A-192:	Seamless Carbon Steel Boiler Tubes for High-Pressure Service.	ASTM E-709:	Practice for Magnetic Particle Examination.
ASTM A-193:	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.	GPSA:	Gas Processors Suppliers Association, P.O. Box 35584, Tulsa, Oklahoma 74153.
		NACE:	National Association of Corrosion Engineers, P.O. Box 218340, Houston, Texas 77218.
		NACE MR-01-75:	Material Requirements — Sulfide Stress Cracking Resistant Metallic Materials for Oil Field Equipment.
		NEMA:	National Electrical Manufacturers Association, 2101 L Street N.W., Washington, D.C. 20210.



NEMA MG-1:	Motors and Generators.	SSPC:	Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213.
NFPA:	National Fire Protection Association, Batterymarch Park, Quincy, Massachusetts 02269.	SSPC SP3:	Power Tool Cleaning.
NFPA 70:	National Electrical Code, Articles 500 and 501.	SSPC SP6:	Commercial Sandblast.
OSHA:	Occupational Safety and Health Administration, U.S. Department of Labor, 200 Constitution Avenue N.W., Washington, D.C. 20210.	TEMA:	Tubular Exchanger Manufacturers Association, 25 North Broadway, Tarrytown, New York 10591.



SECTION 1 GENERAL

1.1 Scope. This standard covers the minimum requirements for a packager supplied, designed and fabricated, skid-mounted, reciprocating, separable or integral compressor with lubricated cylinders and its prime movers used in oil and gas production services. It also includes all necessary auxiliary equipment such as water and gas coolers, exhaust silencer, emission control equipment, inlet air filter, scrubbers, control panel, piping, etc. Required to install an operable unit in compliance with the purchase specifications and with a minimum of field construction and field purchased equipment.

Compressors intended for refinery, chemical or petrochemical services as covered in API 618 — Reciprocating Compressors for General Refinery Services, compressors that are block-mounted, compressors that are non-lubricated, compressors with single-acting, trunk-type (automotive-type) pistons that also serve as cross-heads, and either utility or instrument air compressors that discharge at 125 pounds per square inch (PSIG) or below are specifically excluded from this specification. Diesel engine, gas turbine and steam turbine prime movers are also specifically excluded.

1.2 Data Sheets. Service and operating conditions, material requirements and sub-vendors are set out on the 'API Packaged Compressor Data Sheets — Part 1.' The packager shall indicate the specifics of their offering by completing the 'API Packaged Compressor Data Sheets — Part 2.' One copy of the completed data sheets shall accompany each copy of a quotation. One complete set of 'as-built' 'API Packaged Compressor Data Sheets' shall be included in each copy of the data book furnished by the packager.

- **1.3 Compressor Package Performance Curves.** When specified, compressor package performance curves shall cover the range of operating conditions indicated by the purchaser. Any limitations such as rod load, available driver horsepower, additional clearance required to meet the range of operating conditions, etc., shall be marked on the performance curves.

1.4 Package Arrangement. The arrangement of the package components shall be developed by the compressor packager to provide reasonable access for operation and maintenance.

- **1.5 Drawings.** The packager shall furnish plan and elevation drawings. Pre-fabrication approval or additional drawings may be specified by the purchaser in the 'API Packaged Compressor Data Sheets — Part 1.'
- **1.6 Sound Pressure Level.** Control of the sound pressure level of all equipment furnished shall be the joint effort of the purchaser and the packager. When specified, the equipment furnished by the packager shall conform to the maximum allowable sound pressure level required by the purchaser.

- **1.7 Electrical Location Classification.** All electrical installations shall be in accordance with NFPA 70 except those in Outer Continental Shelf (OCS) areas which shall be in accordance with API RP 14F, with all locations classified in accordance with API RP 500B and so specified by the purchaser on the 'API Packaged Compressor Data Sheets — Part 1.'

- **1.8 Package Installation.** The purchaser shall specify the site conditions (altitude, ambient temperature, etc.) on the 'API Packaged Compressor Data Sheets — Part 1' and whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) and the weather or environmental conditions in which the equipment must operate (including maximum and minimum temperatures, unusual humidity or dust problems). The unit and its auxiliaries shall be suitable for operation in these specified conditions. Purchaser shall specify size limitations, if any.

- **1.9 Torsional Analysis.** The compressor packager will assume responsibility for a torsionally sound system consisting of prime mover, coupling, compressor and flywheel, if required. If the purchaser requires a torsional analysis report, the compressor packager will be responsible to coordinate with the compressor and prime mover manufacturers to produce such a report.

1.10 Definition of Terms. Use of the word 'Design' in any term (such as design horsepower, design pressure, design temperature, or design speed) should be avoided in the purchaser's specifications. This terminology should only be used by the equipment designer and the manufacturer. Terms used in this standard are defined by the following paragraphs:

1.10.1 Maximum Allowable Operating Rod Load. The maximum allowable operating rod load (manufacturer's published rating calculated by manufacturer's standard methods) is the highest force that a manufacturer will permit for continuous operation.

1.10.2 Combined Rod Loading. The 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 the 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.

1.10.3 Rod Reversal. Rod reversal is a change in direction of force in the piston rod loading (tension to compression, or vice-versa), which results in a load reversal at the crosshead pin during each revolution. The duration of rod reversal is usually expressed in degrees of crankcase rotation.



1.10.4 Maximum Allowable Working Pressure. 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 maximum specified temperature. See Paragraph 2.5.1.1 for definition of compressor cylinder maximum allowable pressure rating.

1.10.5 Rated Discharge Pressure. Rated discharge pressure is the highest pressure required to meet the conditions specified by the purchaser for the intended service.

1.10.6 Maximum Allowable Temperature. 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.

1.10.7 Maximum Allowable Speed. Maximum allowable speed in revolutions per minute is the highest speed at which the manufacturer's design will permit continuous operation.

1.10.8 Minimum Allowable Speed. Minimum allowable speed in revolutions per minute is the lowest speed at which the manufacturer's design will permit continuous operation.

1.10.9 Standard Cubic Feet Per Minute or Million Standard Cubic Feet Per Day. Standard cubic feet per minute (SCFM) or million standard cubic feet per day (MMSCFD) refers to the capacity at 14.7 pounds per square inch absolute and 60 deg. F.

1.10.10 Required Capacity. Required capacity is the capacity specified by the purchaser to meet process conditions.

1.10.11 Quoted Capacity. The quoted capacity is the capacity used by the packager to size the compressor at conditions specified by the purchaser. See Paragraph 2.1.1.

1.10.12 Rated Power. Rated power is the highest power required for any of the specified operating conditions.

1.10.13 Normal Operating Point. The normal operating point is the point at which the packager certifies that the quoted capacity and power consumption is met.

1.10.14 Data Book. The data book is a book containing the manufacturer's instructions, parts lists, data sheets, 'as-built' plan and elevation package drawings, 'as-built' 'API Packaged Compressor Data Sheets — Part 2', and other pertinent data.

SECTION 2 COMPRESSOR

2.1 General.

- **2.1.1 Quoted Capacity.** The compressor shall be sized to handle the quoted capacity with the gas analysis, suction pressures, suction temperatures, discharge pressures and site conditions specified in the 'API Packaged Compressor Data Sheets — Part 1.' The number of stages of compression shall accommodate pressure limitations and gas additions or withdrawals as set forth by the purchaser. The package design shall also allow for all pressure drops through the scrubbers, pulsation bottles (if any), coolers and piping from the inlet flange to the outlet flange on the skid.
- **2.1.2 Performance Calculations.** The compressor packager shall use the gas analysis, suction pressures, suction temperature, discharge pressures and site conditions as specified by the purchaser to calculate molecular weight, ratio of specific heats (C_p/C_v), and compressibility factor (Z). The compressor packager shall indicate his values on the 'API Packaged Compressor Data Sheets — Part 2', provide them with the quotation and use them to calculate performance data.
- **2.1.3 Compressor Size.** When specified, the compressor frames shall be furnished with cylinders which, when operating at the specified operating condition(s), shall, as far as practical, load the gas engine to the limit specified in Paragraph 4.2.1 or electric motor to the limit specified in Paragraph 4.3.2.

NOTES: Compressors driven by induction motors shall be sized at the motor operating speed.
- **2.1.4 Forces and Couples.** When specified by the purchaser, the compressor manufacturer shall furnish values for the un-balance primary and secondary forces and couples in the horizontal and vertical planes for the quoted compressor.
- **2.2 Maximum Allowable Speeds.** The maximum allowable average piston speed (in feet per minute) and the maximum allowable speed (in revolutions per minute) may be specified by the purchaser.
- **2.3 Maximum Allowable Discharge Temperature.** The compressor shall be provided with sufficient compression stages and interstage cooling to limit the actual discharge temperature of each stage to 350 deg. F. unless otherwise specified by purchaser. This limit shall hold for all specified operating and load conditions. When specified, the compressor packager shall provide the purchaser with both the estimated actual and the calculated adiabatic discharge temperature rise.

2.4 Rod Loadings.

2.4.1 Maximum Allowable Rod Loading. The maximum operating rod load (gas or combined) shall not exceed the maximum allowable operating rod loading for the compressor or any rod load limitation specified by the purchaser at any specified operating condition. The packager shall quote gas rod load unless specified otherwise by the purchaser. If other than operating rod load calculations are specified, the purchaser will provide operating parameters to the packager for making these calculations.

2.4.2 Piston Rod Load Reversal. For all specified operating load conditions, the axial component of the combined rod loading shall reverse enough to ensure adequate lubrication between the crosshead pin and bushing during each complete turn of the crankshaft.

2.5 Compressor Cylinders.

2.5.1 General.

2.5.1.1 Cylinder Maximum Allowable Working Pressure. The maximum allowable working pressure of the cylinder shall exceed the rated discharge pressure by at least 10 percent or 25 psig, whichever is greater.

2.5.1.2 Cylinder Orientation. Horizontal cylinders shall have bottom discharge connections except where side or top discharge connections are acceptable by the purchaser.

2.5.1.3 Cylinder Maintenance. Cylinders shall be spaced and arranged to permit access and removal for normal maintenance of all components (including covers, packing, valves, or unloaders mounted on the cylinder) without removing the cylinder, major piping or pulsation bottles.

2.5.2 Cylinder/Frame Appurtenances.

2.5.2.1 Cylinder Supports. The cylinder support shall be designed to avoid misalignment or excessive rod run-out during the warm-up period and at actual operating temperature. The cylinder support shall not be attached to the outboard cylinder head. The pulsation bottle, if furnished, shall not be used to support the compressor cylinder unless approved by the compressor manufacturer.

2.5.2.2 Cylinder Body. Cylinders may be non-cooled (no provision for coolant jackets) or cooled (coolant jacket around cylinder bore and cylinder head).

2.5.2.3 Cylinder Bolting. Cylinder heads, stuffing boxes for pressure packing, clearance pockets, and valve covers shall be fastened with either cap-

screws or studs. Studded connections shall be furnished with studs installed. Tapped holes for studs or capscrews in gray iron or ductile iron castings should be designed to provide a nominal engagement of $1\frac{1}{2}$ times the major diameter of the stud or capscrew.

Bolting shall be furnished as follows:

1. Details of threading shall conform to ANSI B1.1 — unified screw threads.
2. Capscrew or stud material, as a minimum, 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 gray iron cylinders. ASTM A-320 shall be used for temperatures of -50 deg. F and below.
3. Hex-head bolting is preferred. Adequate clearance shall be provided at bolting locations to permit the use of socket or box type wrenches.

2.5.3 Cylinder Connections.

2.5.3.1 Gas Connections. Main inlet, outlet and clearance bottle gas connections shall either be flanges or faced bosses to accommodate a flange suitable for the working pressure of the cylinder as specified in Paragraph 2.5.1.1. The bolting of flanges or machined bosses shall conform to the dimensional requirements of ANSI B16.1, B16.42, or B16.5 as applicable. Special connections shall conform to the applicable API, ASME, or ANSI Specification.

2.5.3.2 Indicator Connections. When specified by the purchaser, each cylinder end shall be provided with a $\frac{1}{8}$ -inch, threaded and plugged indicator tap for cylinder performance analysis.

2.6 Valves.

2.6.1 Inlet Valve Average Gas Velocity. Inlet valve average gas velocity shall be computed as follows:

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

Where:

V = Average gas velocity, feet per minute.

D = Piston displacement per cylinder, cubic feet per minute.

A = Product of the actual lift and the valve-opening periphery; total for all inlet valves per cylinder, square inches.

NOTES:

1. Valve lift area used in the above equation shall be shown on data sheets. If lift area is not the smallest area in flow path of valve, it shall be so noted on the data sheet, and velocity shall be computed on basis of the smallest area.
2. Velocities calculated from this formula should be treated only as a general indication of valve per-

formance, and should not be confused with effective velocities based on crank angle, degree of valve lift, unsteady flow, etc. The velocity computed from the above formula is not necessarily a representative index for valve power loss or disc/plate impact.

2.6.2 Valve Designs. Valve designs shall be suitable for operation with any gas specified on the data sheet.

2.6.3 Non-Reversible Valves. The valve design shall be such that valve assemblies cannot be inadvertently interchanged or reversed, for example, fitting a suction valve assembly into a discharge port or inserting a valve assembly upside down.

2.6.4 Valve Guard and Bolting. The valve and cylinder designs shall be such that the valve guard or the assembly bolting (or both) cannot fall into the cylinder even if the valve assembly bolting breaks or unfastens.

2.6.5 Valve Plates or Discs. Valve discs or plates shall be suitable for installation with either side sealing.

2.7 Pistons, Piston Rods, and Piston Rings.

2.7.1 Piston and Rod Locking. Pistons which are removable from the rod shall be attached to the rod by shoulder and lock nut design. All nuts must be secured in place. Locking nuts attaching the piston rod to the piston and to the crosshead shall be tightened in accordance with the compressor manufacturer's torque standards.

2.7.2 Hollow Pistons. Hollow pistons (single or multi-piece) when used shall be self venting.

2.7.3 Piston Wear Bands. Non-metallic wear bands, if required by the manufacturer or specified by the purchaser, shall not overrun valve ports or counterbores by more than one-half the axial width of the wear band.

2.7.4 Piston Rod Hardness. A surface hardness of Rockwell C50 minimum is required on piston rods in the area that passes through the packing. For piston rods in corrosive gas service, see Section 15 — Corrosive Gases — H_2S and CO_2 .

2.7.5 Piston Rod Threads. Piston rods shall be furnished with rolled threads.

2.7.6 Coated Piston Rods. When coated rods are specified, the coating material and base material shall be mutually agreed upon by the purchaser and the manufacturer. The coating material must be properly sealed to prevent corrosion of the base material and subsequent failure of the coating. High velocity and high impact thermal plating, porous electroplating, or suitable plasma spraying are acceptable for coating of piston rods. Metal spray techniques requiring roughening of the surface of the base metal are not permitted because of the potentially destructive stress risers left in the surface. Use of sub-coating under main coating is not permitted.

2.8 Crankshafts, Connecting Rods, Bearings & Crossheads.

2.8.1 Crankshafts. Crankshafts shall be of the compressor manufacturer's standard material and design and shall be heat treated and machined on all working surfaces and fits. They shall be free of sharp corners. Drilled holes or changes in section shall be finished with radii and shall be polished. Forced lubrication passages in crankshafts shall be drilled.

2.8.2 Bearings. Main bearings shall be replaceable sleeve type or anti-friction of the tapered or spherical roller type. Roller bearing selection shall be based on an L10 rating equivalent to 44,000 hours or greater (see AFBMA Std 11) at rated compressor speed and maximum allowable operating rod load. Cylindrical roller or ball type anti-friction bearings are unacceptable.

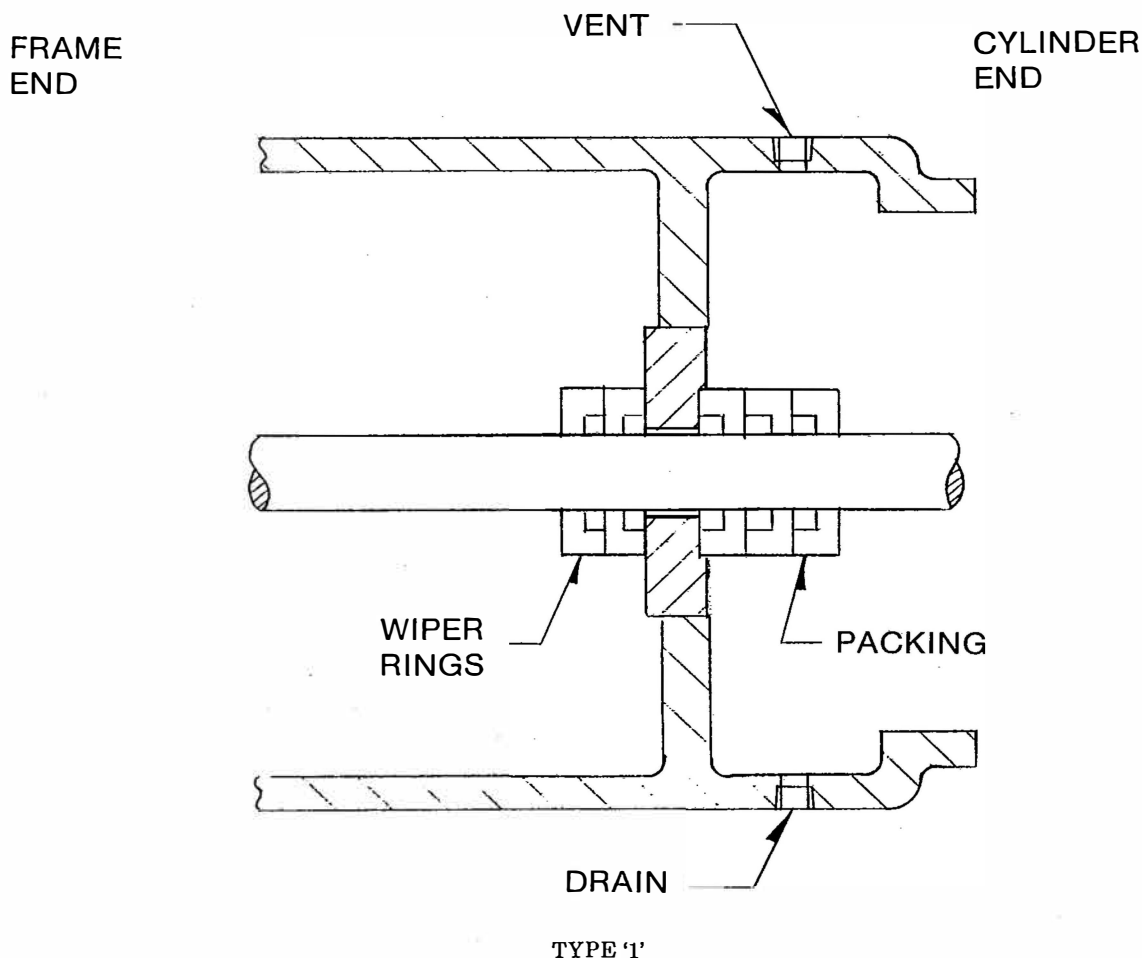
2.8.3 Connecting Rods. Connecting rods shall be of compressor manufacturer's standard material with removable cap. They shall be free of any sharp corners. Forced lubrication passages shall be drilled. Crank pin bearings shall be replaceable sleeve type.

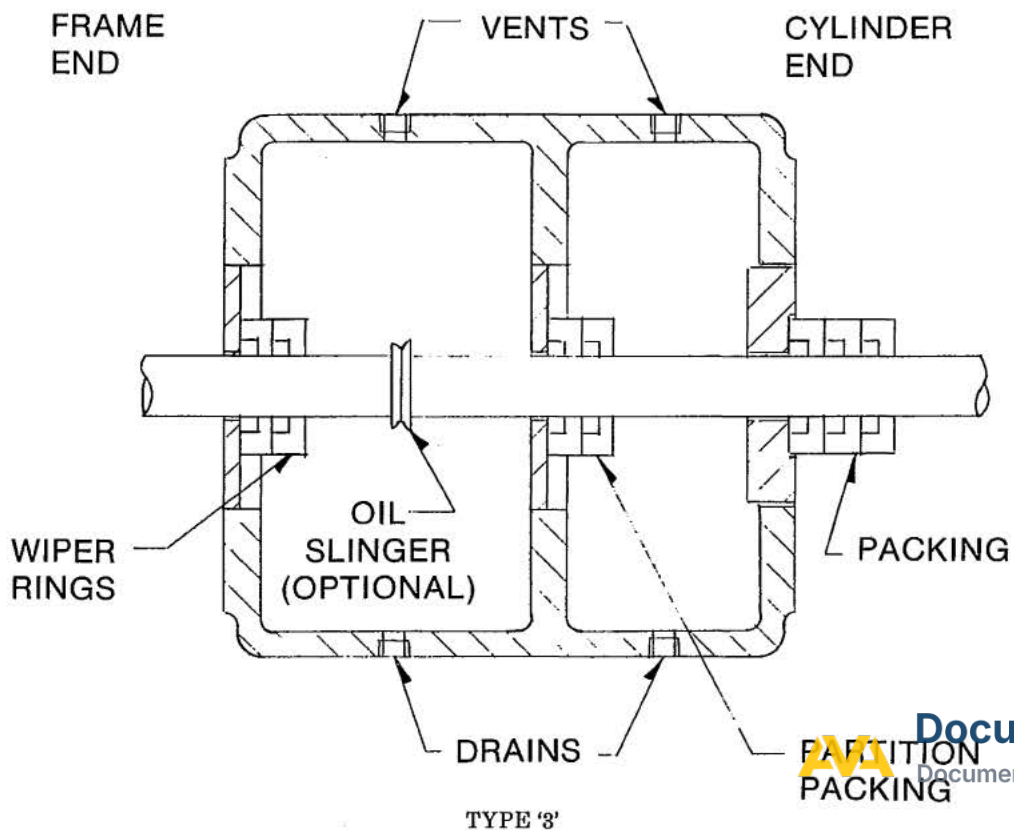
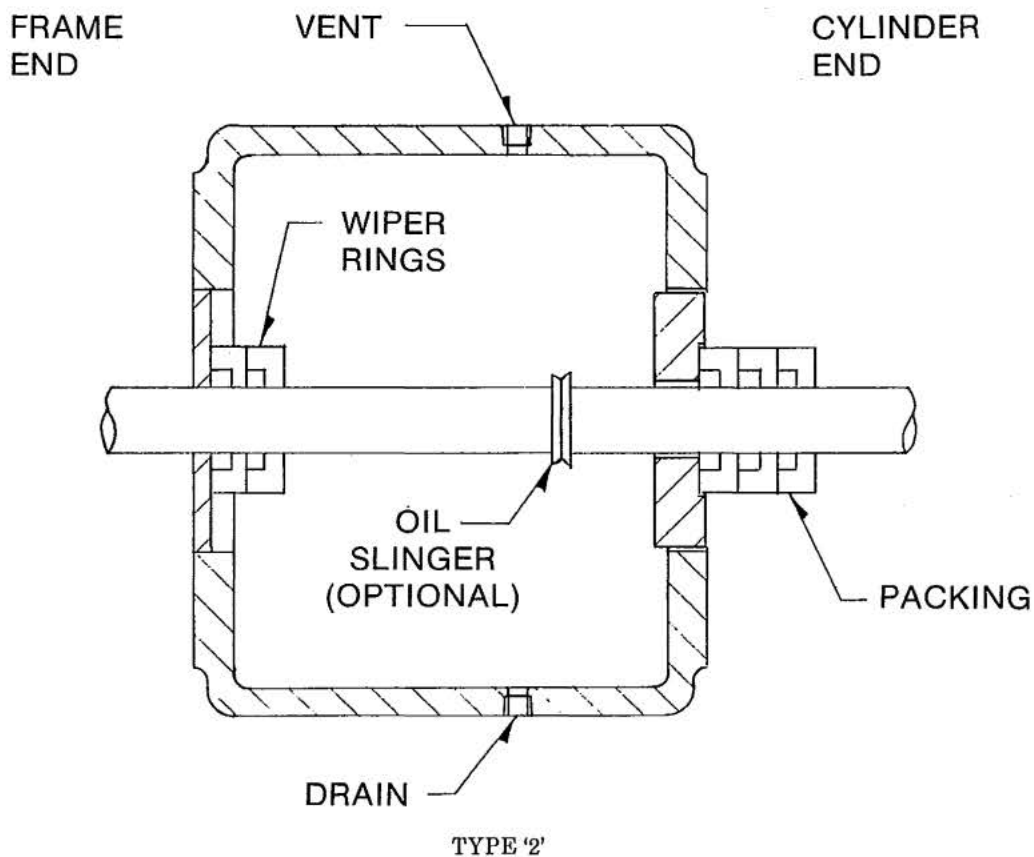
2.8.4 Crossheads. Crossheads shall be compressor manufacturer's standard material and design. Adequate openings for removal of crosshead shall be provided.

2.9 Distance Pieces.

2.9.1 Design. If distance pieces are provided, they shall conform to types '1', '2', or '3' as specified by the purchaser.

NOTES: Short, close-coupled, single compartment (type '1') and long, single compartment (Type '2') are utilized in the majority of oil and gas field applications. Type '1' is used where it is desired to keep overall width of the compressor to a minimum for ease of highway transportation of the package. Type '2' is used when physical separation of the pressure and wiper packing is desired. Type '3' provides double compartments for varying degrees of purging when required. Slinger rings may be added to types '2' or '3' to prevent migration and mixing of oil between the crankcase and the compressor cylinders.





2.9.2 Openings. Openings of adequate size to permit servicing of the packing case shall be provided and shall have bolted access covers, a bottom drain connection, and a top vent connection. Refer to Paragraph 7.19 for drain and vent specifications.

- **2.9.3 Explosion Relief Door(s).** When specified by the purchaser, explosion relief door(s) shall be furnished on the compressor frame or distance piece(s).

2.10 Packing Cases and Pressure Packing.

2.10.1 Type. All oil wiper, intermediate, and gas cylinder pressure packings shall be segmental rings with stainless steel garter springs.

2.10.2 Flanges. Packing case flanges shall be bolted to the cylinder head or to the cylinder with no less than four bolts. Packing case assembly shall have positive alignment features, e.g., cup-to-cup pilot fits and/or sufficient body-fitted tie bolts.

2.10.3 Services. 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 tubed to the outside of the distance piece. Refer to Paragraph 7.19 for drain and vent specifications and Section 15 for corrosive gas applications.

2.10.4 Wiper Packing. Crosshead wiper packing shall be provided to minimize oil leakage from the crankcase.

2.11 Compressor Frame Lubrication System.

2.11.1 Frame Lubrication. The frame lubrication system shall be pressurized and shall have sufficient capacity to provide adequate lubrication at all speeds required to meet the specified operating conditions. Splash systems may be used on horizontal compressors with anti-friction journal bearings operating at 600 rpm or below.

2.11.2 Gauges and Connections. The frame shall have sight oil level gauge and oil filling connection.

2.11.3 Frame Oil Pump. The frame oil pump shall be crankshaft driven either directly, through gears or a chain.

2.11.4 Pressurized System. The pressurized frame lubrication system shall contain a pre-lubrication pump (on motor drive units with sleeve bearings and gas engine drive units with sleeve bearings over 300 bhp), suction strainer, full-flow filter(s) with inlet and outlet pressure gages and replaceable element(s), system relief valve and, if necessary, a system oil cooler. Filter cases and heads shall be suitable for operation at the maximum discharge pressure of the frame oil pump. Full-flow filters with replaceable elements shall be supplied with filtration of 25 microns (nominal) or finer for babbitt and anti-friction bearings and 10 microns (nominal) or finer for aluminum or microbabbitt bearings. The filters shall be located downstream of the cooler. Filters shall not be equipped with a relief valve or automatic by-pass.

Filter cartridge materials shall be corrosion resistant. Metal-mesh or sintered-metal filter elements shall not be used. The design of the filter-cartridge assembly shall assure that internal by-passing cannot occur due to filter-to-cartridge or cartridge-to-cartridge misalignment, inadequate end cover sealing design, or other sealing deficiencies. Additionally, the cartridge collapse differential pressure shall be at least 50 psi and the clean differential pressure shall not exceed 5 psi at design temperature and flow.

2.11.5 Materials. All parts in the crankcase and lubricating oil system shall be of materials suitable for the site environment. For corrosive gas services, refer to Section 15 for material requirements.

- **2.11.6 Oil Level Control.** A compressor frame oil level control device shall be furnished by the compressor packager. A storage tank with level gage shall be furnished if specified by the purchaser.

- **2.11.7 Lube Oil Heater.** When specified by the purchaser, a lube oil heater shall be furnished by the packager.

2.12 Compressor Cylinder Lubrication.

- **2.12.1 Cylinder Lubrication.** Either block distribution lubrication systems or pump-to-point lubrication systems may be furnished for lubrication of compressor cylinder ring travel bore and piston rod packing. The force feed lubricator shall be variable flow and of weather-proof construction and shall be frame mounted, direct, chain or gear driven, and be equipped with a reservoir level indicator. Block distribution lubrication systems shall be complete with no-flow shutdown, rupture relief discs, check valves and carbon steel or Series 300 stainless steel tubing. Line filters, lube meter and fault indicators may be specified by the purchaser for block distribution lubrication systems. For pump-to-point lubrication systems, a sight indicator for each point, check valves and carbon steel or Series 300 stainless steel tubing shall be furnished.

2.12.2 Oil Supply. The force feed lubrication system shall be complete with automatic oil replacement via a gravity feed source, pressurized source, or filtered oil from the compressor crankcase.

- **2.12.2.1 Oil Level Control.** A lubricator reservoir oil level control device shall be furnished by the compressor packager on units with pump-to-point lubrication systems and on block distribution systems when the lubricator pump is not pressure fed. A storage tank with level gage shall be furnished if specified by the purchaser.

2.13 Materials.

2.13.1 General.

2.13.1.1 Materials of Construction. Materials of construction of the compressor and auxiliaries shall be the compressor manufacturer's standard for the

specified operating conditions except as required by the 'API Packaged Compressor Data Sheets — Part 1.'

2.13.1.2 Steel Heads. Steel compressor cylinders shall be equipped with steel heads.

2.13.1.3 Cylinder Material. Materials for pressure containing cylinder parts will be the compressor manufacturer's standard or as specified by the purchaser. The maximum allowable working pressure for various compressor cylinder materials shall not exceed:

Material	Maximum Allowable Working Pressure, psig	
	Thru 8" Cyl Diameter	Over 8" Cyl Diameter
Gray Iron	1,600	1,000
Ductile Iron	2,500	1,500
Cast/Fab Steel	2,500	2,500
Forged Steel	7,500	—

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

2.13.2 Castings and Forgings.

2.13.2.1 Casting Quality. Castings shall be sound and meet the applicable ASTM quality specifications for the material utilized. 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.

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

2.13.2.3 Casting Standard — Gray Iron. Unless otherwise specified by the purchaser, gray iron castings shall be produced in accordance with ASTM Reference Standard A-278 for Pressure Containing Castings. Class shall be specified by the compressor manufacturer.

2.13.2.4 Casting Standard — Ductile Iron. Unless otherwise specified by the purchaser, ductile iron castings shall be produced in accordance with the ASTM Reference Standard A-395 or ASTM A-536 for Pressure Containing Castings. Grade shall be specified by the compressor manufacturer.

2.13.2.5 Casting Standard — Steel. The minimum quality standard allowed for steel castings shall be

ASTM A-216, A-487, A-703, and A-781. Grade shall be specified by the compressor manufacturer.

2.13.2.6 Standard — Forgings. The minimum quality standard allowed for forgings for pressure containing parts shall be ASTM A-668. Grade shall be specified by the compressor manufacturer.

2.13.3 Repair.

2.13.3.1 Casting Repair. Pressure containing gray iron or ductile iron castings shall not be repaired by peening, by burning-in or by welding.

2.13.3.2 Repair by Plugs. Gray iron or ductile iron castings may be repaired by plugging within the limits specified in ASTM A-395. However, unless otherwise agreed upon by the purchaser and the compressor manufacturer, plugs shall not be used in the gas pressure containing wall sections, including the bore under the liner, if any. The drilled hole for a plug shall be subjected to a liquid penetrant examination to ensure that all defective material has been removed.

2.13.3.3 Repairs by Welding. All welding of steel cylinders shall be performed by operators and procedures qualified in accordance with Section IX of the ASME Code.

2.13.3.4 Repair Testing. The compressor manufacturer shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and non-destructively examined for soundness and compliance with applicable qualified procedures.

2.13.4 Material Inspection.

2.13.4.1 Material Samples. Chemical analysis of an as-cast sample from each ladle is not required unless otherwise specified.

2.13.4.2 Inspection Codes. When radiographic, ultrasonic, magnetic particle or liquid penetrant inspection is required or specified, radiography shall be in accordance with Section VIII, Division I, UW-52 of the ASME code; ultrasonic inspection shall be in accordance with Section VIII, Division I, Appendix 12 of the ASME code; magnetic particle inspection shall be in accordance with Section VIII, Division I, Appendix 6 of the ASME code; and liquid penetrant inspection shall be in accordance with Section VIII, Division I, Appendix 8 of the ASME code. When specified, forged parts shall be ultrasonically inspected in accordance with ASTM A-503.

2.13.4.3 Magnetic Particle Inspection. When magnetic particle inspection 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 following limits:

TYPE	DEGREE
I	1
II	2
III	2
IV	1
V	1
VI	1

Defects that exceed the limits imposed above shall be cleaned out to meet the quality standards cited above, as determined by additional magnetic particle inspection before repair welding.

2.14 Power Transmission.

2.14.1 Gears. Speed increasing or reducing gears shall not be used unless otherwise specified by the purchaser.

2.14.2 Couplings. Shaft couplings shall be non-lubricated, flexible, steel disc type with steel or stain-

less steel disc pack as specified by the purchaser except when torsional analysis requires a torsionally soft coupling. Couplings shall be selected for the maximum continuous horsepower rating of the prime mover plus the coupling manufacturer's standard service factor for reciprocating compressor applications.

2.14.3 V-Belt Drives. V-belt drives for compressor applications shall be in accordance with API Std 1B — Specification for Oil Field V-Belting.

2.14.4 Clutches. A clutch power take-off shall not be used unless otherwise specified by the purchaser.

2.14.5 Guards. Flywheels, sheaves, belts, shafts, couplings and similar moving parts shall have removable safety guards that meet occupational safety and health (OSHA) standards.

2.14.5.1 Guard Tolerance. Safety guards shall protect to within $\frac{1}{2}$ inch of stationary housings and shall be sufficiently rigid to withstand deflection and prevent rubbing as a result of bodily contact.

SECTION 3 CAPACITY CONTROL

- **3.1 General.** The compressor capacity may be controlled on the basis of the suction pressure, discharge pressure, flow, or some combination of these parameters. The required capacity variation will be specified by the purchaser. The control system may be mechanical, pneumatic, hydraulic, electric or any combination thereof. The purchaser will specify the parameter to be used for control. If the control signal is from a source furnished by the purchaser, then the purchaser will specify the source, sensitivity and range of the control signal to be utilized by the packager.

- **3.2 Method of Capacity Control.** Capacity control can be obtained by speed variation, clearance variation, bypass, single acting or double acting compressor cylinders, valve unloaders, suction pressure control or any combination thereof. Control operation shall either be automatic with manual over-ride or manual as specified by the purchaser on the 'API Packaged Compressor Data Sheets — Part 1.' Some of these methods require unit shutdown and depressuring to effect a change. The purchaser will specify if such unit shutdowns are acceptable.

- **3.2.1 Speed Variation.** When specified by the purchaser, capacity control can be achieved by prime mover speed variation.

3.2.2.1 Clearance Variation. Clearance variation may be achieved by clearance pockets, valve spacers, cylinder head spacers, clearance plugs, and other methods. These methods may be used alone or in combination. In all cases where clearance volume is added to a compressor cylinder end, the volumetric efficiency must be at least 15%.

NOTE: Volumetric efficiencies less than 15% may cause excessive temperature rise, valve plate flutter, valve plate breakage and possible physical damage to the compressor cylinder.

- **3.2.2.2 Clearance Pockets.** Clearance pockets may be specified by the purchaser and be either the fixed type (pocket clearance is fixed and the pocket is either open or closed) or the variable type (pocket clearance is variable over the range from fully open to closed).

3.2.2.2.1 Variable Pocket Vents. Manually variable volume clearance pockets shall have a non-restricted vent line provided to vent the back side of the variable pocket piston to the suction port of the compressor cylinder, to the suction piping or to the vent system.

- **3.2.2.3 Valve Spacers.** Valve spacers (high clearance assemblies or split valve yokes) used to raise the valve a pre-determined distance above the cylinder valve port may if specified by the purchaser be provided by the compressor manufacturer to meet an operating condition.

- **3.2.2.4 Clearance Bottles.** Clearance bottles for capacity control may be added to the compressor cylinder. They should be designed for the maximum allowable working pressure of the compressor cylinder and hydrotested to $1\frac{1}{2}$ times the MAWP rating and constructed as piping for hydrocarbons (ANSI B31.3) or as ASME code vessels as specified by the purchaser.

3.2.2.5 Cylinder Head Spacer(s). Spacer(s) may be placed between the compressor cylinder body and cylinder head to add clearance volume. This method of capacity control must be approved by the compressor manufacturer to ensure that proper bolting and head gasketing requirements are met.

3.2.2.6 Clearance Plugs. The compressor cylinder head may be furnished with clearance plugs.

NOTES: Clearance plugs usually have two clearance steps. When the plug is inserted into the head or cylinder bore, the clearance is minimum. When the plug is placed outside the head or cylinder bore, the clearance is maximum. Clearance steps between minimum and maximum can be achieved by different length plugs.

3.2.3 Bypass Systems. Bypass systems can be either hot or cold gas and either manual or automatic. Bypass systems shall be equipped for purging before start-up. A pressure relief valve shall be installed to protect equipment which has a pressure rating lower than the pressure of the bypass gas.

- **3.2.3.1 Start-Up Bypass.** A bypass for start-up only is usually a hot gas bypass (from the discharge of the final stage to the inlet side of the compressor with no cooling of the gas) and manually operated. This type of bypass system shall not be utilized for capacity control. It will be specified by the purchaser when required.

- **3.2.3.2 Capacity Control Bypass.** When specified by the purchaser, a manual or automatic cold gas (from downstream of the aftercooler or discharge scrubber, if furnished, back to the inlet scrubber) bypass system for capacity control shall be furnished.

3.2.4 Valve Removal or Unloading.

3.2.4.1 Valve Removal. Removal of all the suction valves from the head-end of a double acting compressor cylinder is permitted to completely unload that end of the cylinder. Suction or discharge valves shall not be removed from the crank-end of a compressor cylinder without specific approval of the compressor manufacturer.

3.2.4.2 Valve Unloaders. Compressor cylinder capacity control can be accomplished with valve



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depressors or plug-type unloaders. Valve depressors, when used, shall be installed on all suction valves of the cylinder end involved.

NOTES: *Where plug-type unloaders are used, the number of unloaders is determined by the area per plug opening, the total of which must be equal to or greater than one-half of the total free lift area (or least flow area) of all suction valves on that end.*

When valve depressors are used only for start-up, and never for capacity control, the compressor manufacturer may approve a reduced number of unloaders. For start-up with plug unloaders, only one per cylinder end is needed.

3.2.4.3 Automatic Valve Unloading. When specified, the packager shall provide a system of properly sequenced unloader operation. Pneumatically

operated unloaders with no manual over-rides shall be piped by the packager in such a manner that inadvertent non-sequenced operation shall not occur.

3.2.4.4 Unloader Operator. Pneumatically operated unloaders shall be suitable for operation with any gas specified on the 'API Packaged Compressor Data Sheets — Part 1', and if air operated, they shall be designed so that the air used for unloading cannot be mixed with the gas being compressed even in the event of failure of the diaphragm or another part.

3.2.5 Suction Pressure Control. When specified by the purchaser, a suction pressure reducing valve shall be used to limit the suction pressure to a set value in order to control capacity of the unit.

SECTION 4 PRIME MOVER

- **4.1 General.** The type of prime mover (gas engine or electric motor) will be specified by the purchaser. The prime mover shall be sized to meet the maximum specified operating conditions and shall be in accordance with applicable specifications as stated in the inquiry.

4.2 Spark Ignited Gas Engines.

4.2.1 Rated Brake Horsepower. Unless otherwise specified by the purchaser, the gas engine shall be sized for the greatest horsepower required for any of the compressor operating conditions plus accessory horsepower, for the specific location, without exceeding the engine manufacturer's standard published rating criteria for continuous duty service. The engine manufacturer's continuous duty service is defined as the load and speed which can be applied without interruption after taking into consideration site conditions of altitude, temperature and fuel gas composition as listed on the data sheets.

4.2.2 Operating Speed. The packager shall not apply an engine at an operating speed either greater or less than the manufacturer's recommended continuous duty speed range.

- **4.2.3 Starting Systems.** Electric, air or gas starting systems for the engine driver will be specified by the purchaser.

4.2.3.1 Air or Gas Starting System. Unless otherwise specified, the packager's air or gas starting system shall include the following:

1. Manual block valve to isolate the system.
- 2. If required, a regulator to provide proper starter pressure. Purchaser will specify source and minimum/maximum pressure of air or gas available for the starting system.
3. Safety relief valve. See Paragraph 7.20 for sizing, setting criteria, and venting.
4. Spring loaded (spring to close) quick opening valve.
5. Air or gas starter with lubricator and strainer.
6. The starter vent piping (sized for at least the same diameter as the starter exhaust connection) shall be piped to skid edge unless otherwise specified by the purchaser.

NOTES: *The safe disposition of the starter vent gas must be considered in the installation and is the responsibility of the purchaser.*

4.2.3.2 Electric Starting Systems. Electric starting systems shall not be used in classified locations as defined by API RP 500B. When the packager

provides electric starting systems for un-classified locations, they shall include the following:

1. Electric starting motor with starting control.
2. If specified, a battery set with ampere-hour capacity sufficient to start the engine at the lowest specified ambient temperature.
- 3. If specified, a charging alternator of sufficient capacity to charge the battery set furnished.

4.2.4 Air Filters. The engine manufacturer's standard dry-type air intake filter, suitable for outdoor service, shall be provided unless the purchaser has specified otherwise. Air shall not be taken from inside enclosed buildings not adequately ventilated in accordance with API RP 500B.

- **4.2.4.1 Other Air Filters.** Other types of air filters, when specified by the purchaser, shall conform to the following minimum criteria:

1. The micron particle rating shall be that as recommended by the engine manufacturer.
2. Site environmental conditions (blowing sand, ice, snow, etc.) shall be taken into consideration.
3. The filter shall be oriented to allow in-service maintenance.

4.2.4.2 Minimum Design Requirements. The following features shall be considered in the design of an air intake system:

1. Piping and supports for remote mounted air filters will be furnished by the purchaser unless otherwise specified.
2. Remote mounted air filters shall have internal surface corrosion protection of inlet piping.
3. Remote mounted air filters shall be placed so that ground dust or snow will not clog the filter.
4. All ducting, including air cleaner-to-manifold connections, must be air-tight to avoid the intake of unfiltered air.
5. Restricted inlets, sharp or numerous bends, and undersized piping shall be avoided. Maximum pressure drop shall not exceed engine manufacturer's recommendation.
- 6. Pressure drop indicator when specified by the purchaser.

4.2.5 Exhaust System. A standard industrial type exhaust muffler/silencer shall be provided by the packager unless the purchaser has specified otherwise.

• **4.2.5.1 Other Muffler/Silencers.** Other types of exhaust muffler/silencers, when specified by the purchaser, shall conform to the following minimum criteria as specified on the 'API Packaged Compressor Data Sheets — Part 1':

1. Sound attenuation.
2. Personnel protection.
3. Spark arresting capability.

4.2.5.2 Minimum Design Requirements. The following features shall be considered in the design of an exhaust system:

1. The exhaust system shall be properly anchored and supported, include all interconnecting piping, and direct the expansion of the piping involved away from the engine. If an expansion joint is required, it shall be stainless steel.
2. Muffler/silencer shall be painted with high temperature resistant aluminum paint or equal.
3. Exhaust piping shall not exceed the engine manufacturer's back pressure limitations.
4. Provisions shall be made to prevent rain water from entering the system.

4.2.5.3 Insulation and guarding. Insulation and/or guarding of hot metal surfaces shall not be provided unless specified otherwise by the purchaser.

4.2.6 Engine Shutdowns. See Section 10 — Shutdowns, Alarms and Annunciators.

4.2.7 Engine Ignition Systems. The engine shall be equipped with a low tension capacitor discharge ignition system, non-shielded, unless otherwise specified by the purchaser. The system shall include generator, high tension coils, low and high tension cables and spark plugs. All components shall be of weather-protected design or fitted with weather-covers to prevent rain from directly contacting or accumulating in system components.

• **4.2.8 Engine Emissions.** Compliance with local, state, and federal air emission regulations is the responsibility of the purchaser. To assist the purchaser in the selection of equipment as well as supplying the applicable regulatory body with accurate emissions data, the packager will provide either manufacturer's performance data or actual stack test data if specified by the purchaser. The purchaser will furnish the fuel composition and the known emission level limits for the installation on the 'API Packaged Compressor Data Sheet — Part 1' when requesting emissions data.

• **4.2.8.1 Required Data.** When specified, emissions data shall be supplied for the following compounds at specified engine load conditions:

Nitrous Oxides
Carbon Monoxide

Non-Methane Hydrocarbons
Sulfur Dioxide

The basis for obtaining the amounts of these compounds will be:

1. The quoted engine shall be loaded to either the rated horsepower shown on the quotation or the manufacturer's nameplate rating as specified by the purchaser.
2. The fuel composition used for the test shall be shown and effects, if any, related to the differences in the test and actual fuel shall be noted.
3. The air:fuel ratio shall be specified within the manufacturer's recommended range.
4. Units of grams per horsepower-hour or tons per year shall be used.

4.2.8.2 Emission Control Device. If a catalytic converter or other external device is quoted to meet the air emissions requirements specified by the purchaser, the rated horsepower quoted shall reflect the effects, if any, of the additional back-pressure or heat loads placed on the driver by the device. Any special operational considerations, fuel composition, air:fuel ratio or lubrication specifications shall be clearly stated in the packager's quotation.

4.2.9 Engine Lubrication System. Engines shall be equipped with the engine manufacturer's standard lube oil system unless otherwise specified.

• **4.2.10 Oil Level Control.** A crankcase oil level control device shall be furnished by the packager. A storage tank with level gage shall be furnished by the packager if specified by the purchaser.

4.2.11 Fuel Gas System. Unless otherwise specified, the fuel system shall include:

1. Pressure-reducing regulator with downstream pressure gage and isolating valve.
2. Relief valve sized for maximum output capacity of pressure-reducing regulator based on maximum supply pressure and orifice installed in regulator. See Paragraph 7.20 for sizing, setting criteria and venting.
3. Fuel system manual block valve.
4. Automatic valve in fuel system to shut off fuel to the engine and vent engine side of fuel system when engine is shut down.
5. Fuel filter/separator, if specified, shall be installed downstream of the high pressure regulator.

• **4.2.12 Fuel Gas Composition.** The fuel gas composition and pressure, if different than the compressed gas, shall be as set forth in the 'API Packaged Compressor Data Sheets — Part 1'. Any contaminants are to be listed by the purchaser in 'Part 1' and the



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engine manufacturer shall be consulted for fuel treatment requirements and special precautions.

- **4.2.13 Crankcase Explosion Door(s).** Crankcase explosion relief door(s) shall be furnished on the engine crankcase when specified by the purchaser.

4.3 Electric Motors.

- **4.3.1 Motor Description.** The purchaser will specify on the 'API Packaged Compressor Data Sheets — Part 1', the motor description including electrical data, starting conditions, type of enclosure, area classification, type of insulation, service factor, ambient temperature, elevation, and accessories such as temperature detectors, vibration sensors, heaters and instrumentation.

4.3.2 Rated Brake Horsepower. The motor power rating including service factor, if any, shall be a minimum of 110% of the greatest horsepower required for any of the specified compressor operating condi-

tions and the design of the motor shall conform to the NFPA 70 and NEMA MG-1 specifications.

4.3.3 Motor Current Variations. The inertia of the rotating parts of the combined motor/compressor installation shall be sufficient to limit motor current variations to a value not exceeding 66% of the full load current in accordance with Paragraph 20.82 of NEMA MG-1 for induction motors and Paragraph 21.84 of MG-1 for synchronous motors for all specified compressor operating conditions.

4.4 Guards. Flywheels, sheaves, belts, shafts, couplings and similar moving parts shall have removable safety guards that meet occupational safety and health (OSHA) standards.

4.4.1 Guard Tolerance. Safety guards shall protect to within $\frac{1}{2}$ inch of stationary housings and shall be sufficiently rigid to withstand deflection and prevent rubbing as a result of bodily contact.

SECTION 5 COOLING SYSTEM

5.1 General. API 661 — Air cooled heat exchangers for General Refinery Services are not included in the scope of this specification.

5.2 Engine. An engine cooling system shall include the following features, as appropriate:

1. Engine coolant section(s) as required by the engine manufacturer for engine lube oil, engine turbocharger air aftercooler (if required) and engine jacket cooling.
2. Elevated deaerating type reservoir with gage glass, vent line, coolant level switch, overflow, filling connection, and drain. Gage glasses are not required on engine radiators.
3. Thermostatic coolant temperature control per engine manufacturer's recommendation.
4. Plugged manual drain connection(s) to completely drain equipment and system.

5.3 Compressor.

5.3.1 Circulated Coolant. When coolant cooled cylinders are furnished, a compressor cylinder jacket cooling system shall be provided either separate or integral with the engine cooling system to provide coolant to the compressor cylinders within the temperature limits recommended by the compressor manufacturer for the specified compression services. The cylinder cooling system piping shall be equipped with vents and low point drains. Manual block valves to permit working on the compressor unit or auxiliary equipment without draining the engine cooler shall be furnished.

5.3.1.1 Cylinder Jacket System. When furnished, the cylinder jacket system must be designed to positively prevent leakage of gas into the coolant.

NOTES: The purchaser is cautioned regarding the following:

1. Coolant inlet temperatures less than 10 deg. F. greater than gas inlet temperatures may cause gas constituent condensation.
2. Insufficient coolant flow or low coolant velocity may cause fouling of the cylinder jacket system.
3. Coolant exit temperatures more than 30 deg. F. above gas inlet temperature may cause capacity reduction.

5.3.1.2 Sight Flow and Temperature Indicators. Sight flow and temperature indicators shall be furnished when specified by the purchaser.

5.3.2 Thermo-Siphon and Static Cooling. When applicable, the compressor cylinder jacket cooling system may be either static or thermo-siphon type where the compressor discharge temperatures are

within the temperature limits recommended by the compressor manufacturer for the intended compressor cylinders and gas compression services.

5.3.3. Rod Packing Cooling. Unless otherwise specified on the 'API Packaged Compressor Data Sheets — Part 1', the following pressure packing case cooling criteria shall be followed:

1. The compressor manufacturer's standard design may be used for packing pressures up to 2500 psig on piston rods 2½ inches in diameter or less.
2. Cooled packing cases are required for packing pressures above 2500 psig. Internal tubing of Series 300 stainless steel and forged fittings shall be furnished by the compressor manufacturer.
3. When packing cooling is required, the compressor manufacturer is responsible for advising the compressor packager of minimum requirements such as flow and pressure, pressure drop, temperature, filtration, corrosion protection and type of coolant.

5.3.4 Frame Lube Oil. A compressor frame oil cooling system when required by the compressor manufacturer shall be provided either separate (with thermostat) or integral with the engine cooling system to provide coolant to the compressor frame shell and tube lube oil cooler.

5.3.5 Gas Cooling. Gas intercooling shall be provided as required and gas aftercooling shall be provided as specified by the purchaser.

5.4 Types of Coolers.

5.4.1 Air Exchange Coolers. Units which require air cooling of several streams shall be equipped with finned tube exchangers mounted in one compact cooler assembly.

5.4.2 Radiator. Units requiring air cooling of only engine jacket coolant may be equipped with a radiator type (automotive type) cooler sized for the site conditions.

5.5 Air Exchange Cooler Design Criteria.

5.5.1 Properties. Physical and thermal properties of the fluids to be cooled shall be obtained from recognized sources, TEMA Standards or GPSA Data Books.

5.5.2 Glycol/Water. The coil sections intended for cooling engine and compressor cylinder jackets, if any, shall be designed to cool a fifty percent (50%) solution of ethylene glycol in water or other special solutions as required by the engine or compressor manufacturer at maximum design ambient temperature.

5.5.3 Pressure. The maximum allowable working pressure of gas sections shall be at least the maximum operating discharge pressure plus 50 psi or 10 percent of the maximum operating discharge pressure, whichever is greater, at an assumed temperature of 350 deg. F. The maximum allowable working pressure of the oil or coolant sections shall be 150 psig minimum.

5.5.3.1 Code. An ASME code stamp on the gas cooler sections shall be supplied unless otherwise specified by the purchaser.

5.5.4 Heat Rejection and Flow Rate. Heat transfer equipment for packaged compressor units shall have the following design flow rates and heat loads:

1. **Gas Cooler** — 100 percent of calculated rates based on the compressor normal operating point including the latent heat for water/hydrocarbon saturated gases with a minimum fouling factor of 0.002.

2. **Engine Jacket Coolant, Oil and Auxiliary Coolers** — Equipment manufacturer's recommended excess capacity but not less than 110 percent of equipment manufacturer's estimate of heat rejection and a minimum fouling factor of 0.0005 for coolant and 0.001 for oil.

5.5.5 Design Assumptions. Unless otherwise specified by the purchaser, the following criteria shall be used for design:

1. Ambient temperature = 100 deg. F.
2. Site Elevation = 1500 feet
3. Suction gas temperature = 90 deg. F.
4. Intercooler gas outlet temperature = 130 deg. F.
5. Aftercooler gas outlet temperature = 120 deg. F.
6. Specific Gravity = 0.65
7. 'K' Value = 1.26
8. Allowable Pressure Drop

Operating Pressure

35 psia and below — 5% not to exceed 1 psi
 36 psia to 250 psia — 3% not to exceed 5 psi
 251 to 1000 psia — 2% not to exceed 10 psi
 1001 psia and above — 1%

9. Parasitic Fan HP = 5% of engine bhp.

NOTES: 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 and acoustic (organ-pipe) frequencies should not be coincident with pulsation frequencies generated by the compressor.

5.6 Arrangement and Construction.

5.6.1 Cooler Air Flow. Air cooled exchangers with fans 48 inches in diameter or larger shall be arranged so that air is not drawn from or directed toward the prime mover.

5.6.1.1 Fan Tip Speed. Fan tip speed shall not exceed 14,000 feet per minute unless otherwise specified by the purchaser.

5.6.2 Draft. Either induced draft or forced draft air circulation may be used with cooler assemblies other than radiators.

5.6.3 Fins. The ends of fins shall be stapled or brazed unless otherwise specified by the purchaser.

5.6.4 Tube Material. Steel tubes shall be used unless specified otherwise by the purchaser.

5.6.4.1 Admiralty. If admiralty tubes are specified, they shall comply with ASME SB-III UNS Number 44300, 44400, or 44500 (inhibited) with thickness as follows:

1. 0.042 inch or 19 bwg minimum for tubes smaller than ¾ inch OD.
2. 0.049 inch or 18 bwg minimum for tubes ¾ inch OD and larger.

5.6.4.2 Steel. Steel tubes shall comply with ASME SA-179 for seamless tubes or ASME SA-214 for welded tubes.

1. 0.060 inch or 16 bwg minimum for all size tubes.

5.6.5 Cleanouts. Air cooled exchangers, other than radiator type, shall have header plugs to facilitate cleanout and replacement of each tube.

5.6.6 Air Flow Control. For air cooled exchangers in services and/or plant sites subject to freezing, hydrate formation, high viscosity, etc., the minimum fluid temperature shall be limited by control of air circulation by means of louvers, automatic variable pitch fan blades, re-circulation system, etc. Automatic control shall be furnished when specified by the purchaser.

5.6.6.1 Louver Operators. Operating levers for manual louvers shall be at an elevation accessible from ground level and have position indicators on any louvers which can not be seen from ground level.

5.6.7 Screens and Guards. When specified by the purchaser, bug screens and hail guards shall be furnished. Bug screens shall be of #10, mesh galvanized hardware cloth and hail guards shall be ½ inch - ¾ inch expanded metal. Screens and guards shall be designed sufficiently large to minimize any pressure drop into the cooler and be easily removable for cleaning.



5.6.8 Fan Support. Fans for air cooled exchangers, other than standard engine radiators, shall be supported by a tripod, or equal structure.

5.6.9 V-Belts. V-Belt drives shall be designed and constructed in accordance with API Std 1B — Specification for Oil-Field V-Belting.

5.6.10 Lubrication. Lubrication supply lines of the fan drive system shall be piped to a location to permit lubrication safely without shutting the unit down and without guard removal.

5.6.11 Piping Supports. Piping supports shall be attached to the cooler structure and not welded to the cooler sheet metal.

5.6.12 Guards. Sheaves, belts, shafts, couplings and similar moving parts shall have removable safety guards that meet occupational safety and health (OSHA) standards.

5.6.12.1 Guard Tolerance. Safety guards shall protect to within $\frac{1}{8}$ inch of stationary housings and shall be sufficiently rigid to withstand deflection and prevent rubbing as a result of bodily contact.

SECTION 6 PRESSURE VESSELS

6.1 General.

6.1.1 Code. Pressure vessels handling compressed gas shall be constructed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division I (latest edition), and code stamped if the working pressure is 15 psig or greater and with an internal diameter greater than six inches.

6.1.2 Material. Pressure vessels shall be fabricated from pipe or rolled plate in accordance with material specifications contained in the ASME Boiler and Pressure Vessel Code, Section VIII.

6.1.3 Corrosion Allowance. Corrosion allowance for pressure vessels will be specified by the purchaser.

6.1.4 Flanges. Weldneck raised face flanges shall be used unless specified otherwise. Ring type joints or spiral wound metallic gaskets with centering ring shall be employed for ANSI Class 900 flanges or higher. Slip-on flanges, when used, shall be installed with full fillet welds and full internal fillets.

6.1.5 Connection Size. Connections up to 2 inch diameter may be threaded. Only manufactured threadlets shall be used. For connections above 2 inch nominal diameter, only welded connections will be acceptable.

6.1.6 Small Connections. Connections 1½ inches in diameter and smaller shall be designed in accordance with Paragraph 7.2.

6.2 Scrubbers.

6.2.1 Internals. Internals shall be designed to ensure that the inlet stream is not deflected toward the upper portion of the vessel.

6.2.2 Arrangement. Spacing of the inlet nozzle, mist extractors, liquid level controls and high liquid level shutdowns shall be such that the scrubber functions to prevent liquid from reaching the compressor cylinders.

6.2.3 Safety Switch. Provision shall be made to keep internal safety switch floats out of high velocity areas.

6.2.4 Mist Extractor. 300 series stainless steel or monel, vane or mesh type mist extractors shall be furnished unless otherwise specified by the purchaser. Mesh type mist extractors, when furnished, shall be supported both above and below the mesh material.

6.2.5 Equipment. Equipment furnished on scrubbers shall be manual drain, automatic drain valve with liquid level controller, and high level safety shutdown switch. When specified, a reflex type liquid level

gage with cocks and check valves and a pressure indicator with isolating valve shall be furnished.

6.2.6 Diameter. The required scrubber diameter shall be based on the scrubber class specified and determined using the procedure as follows unless otherwise specified by the purchaser:

1. 'K' factors for determining maximum allowable superficial velocity for vertical compressor scrubbers are listed for each scrubber service class described as follows:

Scrubber Service Class 'A', K = 0.35

Scrubbing for design conditions only. No capacity for liquid slugs from inlet piping, or condensation mists produced by inlet valve throttling. No capacity for gas flow increases due to start-up surges, pressure changes, or compressor clearance adjustments. No capacity for changes in gas and liquid densities and temperature.

Scrubber Service Class 'B', K = 0.25

Scrubbing for design conditions plus moderate additional scrubber capacity. Generally used only for interstage scrubbers without sidestreams.

Scrubber Service Class 'C', K = 0.18

Scrubbing for design conditions plus substantial additional scrubber capacity. Generally used only for suction scrubbers.

2. Maximum allowable superficial velocity, the gas actual volume flow rate, and the minimum scrubber diameter required shall be calculated by the following formulas:

$$V_a = K \sqrt{\frac{d_l - d_g}{d_g}}$$

$$d_g = \frac{P_o * S_g * 28.96 \text{ lbs. of air/mol}}{T_o * Z * 10.73 \text{ psia-scf/mol-deg. R}}$$

$$Q_a = \frac{Q_s * S_g * 28.966 \text{ lbs. of air/mol}}{379.5 \text{ scf/mol} * 86,400 \text{ sec./day} * d_g}$$

$$D = \sqrt{\frac{Q_a * 144}{V_a * 0.7854}}$$

Where:

V_a = Maximum allowable superficial velocity through scrubber (ft./sec.).

d_l = Density of the liquid at operating conditions (lbs./cu. ft.)

d_g = Density of the gas at operating conditions (lbs./cu. ft.).